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MOTION IN FLIGHT SIMULATION: AN ANNOTATED BIBLIOGRAPHY.(U)
JUL 78 J A PUIG, W T HARRIS, & L RICARD

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MOTION IN FLIGHT SIMULATION:
AN ANNOTATED BIBLIOGRAPHY

Joseph A. Puig
Human Factors Laboratory

William T. Harris
Advanced Simulation Concepts Laboratory

and

Gilbert L. Ricard
Human Factors Laboratory

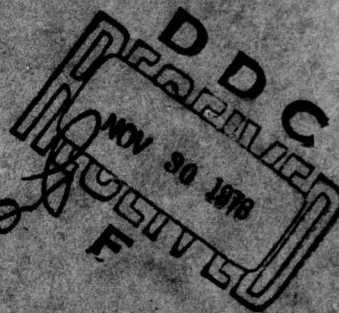
Naval Training Equipment Center
Orlando, FL 32813

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Technical Report: NAVTRAEQUIPCEN IH-298

Motion in Flight Simulation:
An Annotated Bibliography

JOSEPH A. PUIG
Human Factors Laboratory

WILLIAM T. HARRIS
Advanced Simulation Concepts Laboratory

and

GILBERT L. RICARD
Human Factors Laboratory

July 1978

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VINCENT J. SHARKEY
Head, Human Factors Laboratory

FRANK J. OHAREK
Acting Head, Advanced Simulation Concepts Laboratory

JAMES S. DUVA
Director
Research and Technology Department

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In support of Project 7744 - Motion Drive Signals for Flight Simulators, a review of the literature concerning motion simulation was conducted. Abstracts were included for 682 references. A primary objective of this review was to compare data from the various studies to identify general trends on the effects of motion on performance and training. The publications were listed alphabetically by author, chronologically, and also grouped into eight major categories as follows: reviews and bibliographies; equipment descriptions;		

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requirements; algorithms and drive techniques; effectiveness of motion; evaluation; vertical motion, and cost effectiveness.

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PREFACE

In all, 682 documents are annotated in this bibliography, each annotation providing a nonevaluative summary or abstract of a document's contents. The text of the report attempts to synthesize the results from various studies grouped into particular categories. We cannot claim that this bibliography is comprehensive as some material has not been available and the time constraints imposed by the necessity of meeting project deadlines have curtailed our search activities to some extent. If the reader knows of any pertinent documents which we have overlooked, we would appreciate being notified of the title, author, publisher and date, or better still -- having a copy of the publication forwarded to us.

The Defense Documentation Center (DDC) was a principal document source which provided a search of Work Unit Summaries and reports concerning motion simulation. In addition, searches were provided by the NASA Scientific and Technical Information Facility, the National Institute of Education, US Department of Health, Education and Welfare, the Smithsonian Science Information Exchange, Inc., and the Defense Logistics Studies Information Exchange, US Army Logistics Management Center.

Many titles were obtained from previous research studies such as the Boeing report by Graham (1968) which listed 195 references about 20 of which concerned motion simulation directly and many which dealt with vibration, turbulence and acceleration.

Many persons provided assistance in the preparation of this technical report. Outstanding contributors who deserve our grateful acknowledgement, were: Dr. Rex C. Thomas of the Human Factors Laboratory* who contributed significantly to this project by compiling several hundred references during the early part of this project; Miss Harriet Deas and Mr. Ray Miller who provided computer programming services; Miss Billie Campbell of NAVTRAEQUIPCEN's Technical Library who tracked down numerous elusive documents; Mrs. Sara "Pat" Backstrom, Mrs. Cheryl Evans, and Mrs. Jeanette Price who cheerfully typed hundreds of abstract cards; and last -- not in order of importance but because she put the finishing touches on it -- Mrs. Muriel Cook, who painstakingly organized and typed the manuscript while doing a cryptanalysis of our handwriting.

We are also grateful to Mr. John C. Dusterberry, Special Assistant to the Director, NASA Ames Research Center for contributing Tables 1 and 2 on motion systems in government and industry which originally appeared in ASRO Report 75-1, A Technical Assessment of U.S. Army Flight Simulation Capability and Requirements for Aviation Research and Development by Burke, J.; Dunn, R. S.; Dusterberry, J.; Key, D. L.; Sinacori, J. B.; and Xerakis, G., April 1975. Mr. Dusterberry also sent us several recent reports that had escaped our search.

*Currently with the Fleet Combat Direction Systems Support Activity, Dam Neck, Virginia.

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Thanks are also due the following persons who contributed relevant material to this document:

Mr. Robert Browning, Training Analysis and Evaluation Group
Dr. Stanley C. Collyer, Human Factors Laboratory, NAVTRAEQUIPCEN
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Mr. Carl R. Driskell, System Engineering, PM Trade, NAVTRAEQUIPCEN
Mr. Andrew M. Junker, 6570th Aerospace Medical Research Laboratory
Ms. Gayle E. Nance, Patent Counsel, NAVTRAEQUIPCEN
Mr. Don Norman, Human Factors Laboratory, NAVTRAEQUIPCEN
Mr. Vincent J. Sharkey, Human Factors Laboratory, NAVTRAEQUIPCEN
Airman Lois Short, Williams Air Force Base, AZ
Capt. Thomas W. Showalter, USAF, Ames Research Center, CA

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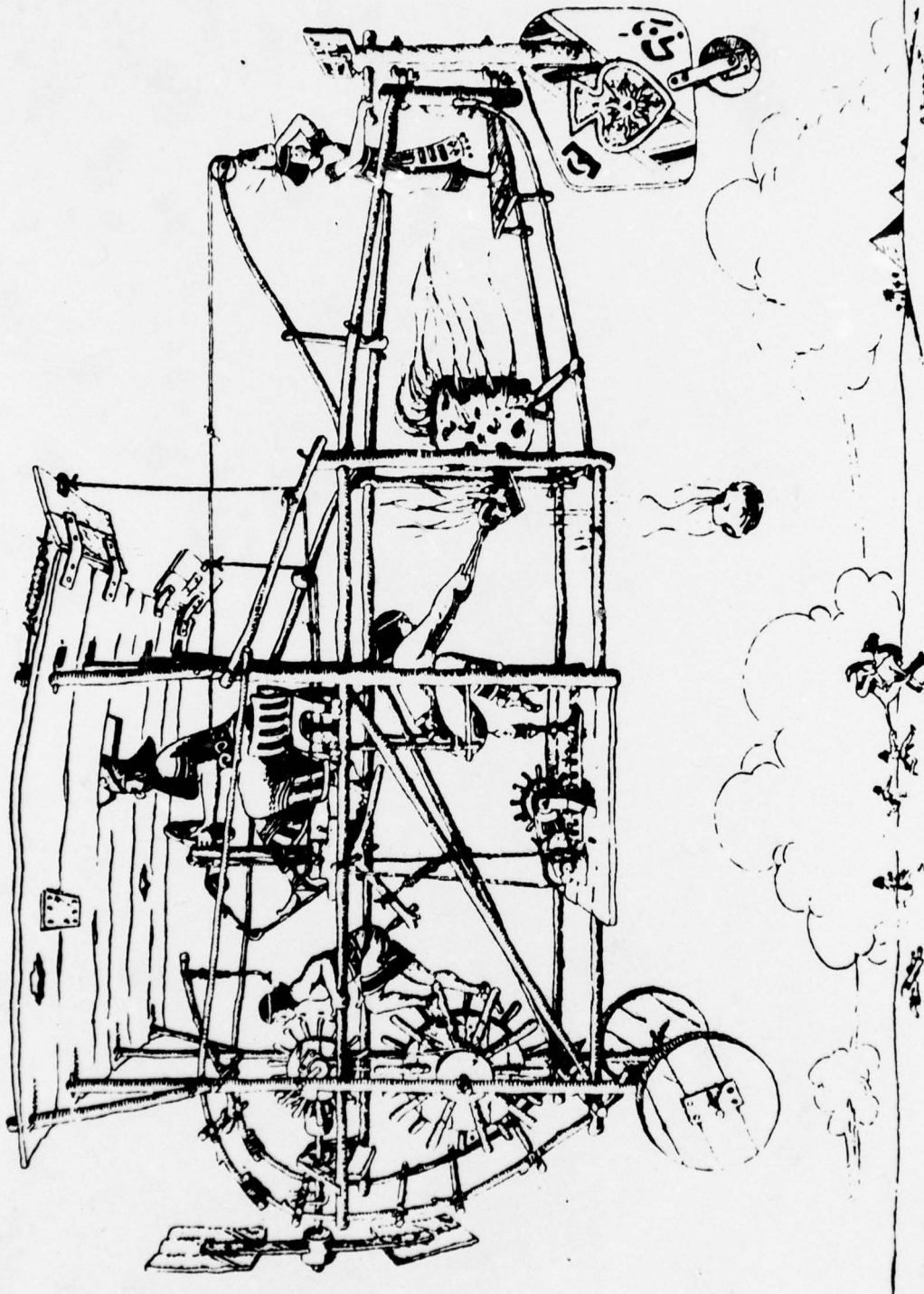
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FRONTISPIECE - TUT-ANKH-AMEN'S BATTLEPLANE (Drawn from plans found during the recent excavations.)
Early In-Flight Motion Cueing System

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SECTION I

INTRODUCTION

"If we could first know where we are, and whither we are drifting, we could better judge what to do and how to do it."

Abraham Lincoln

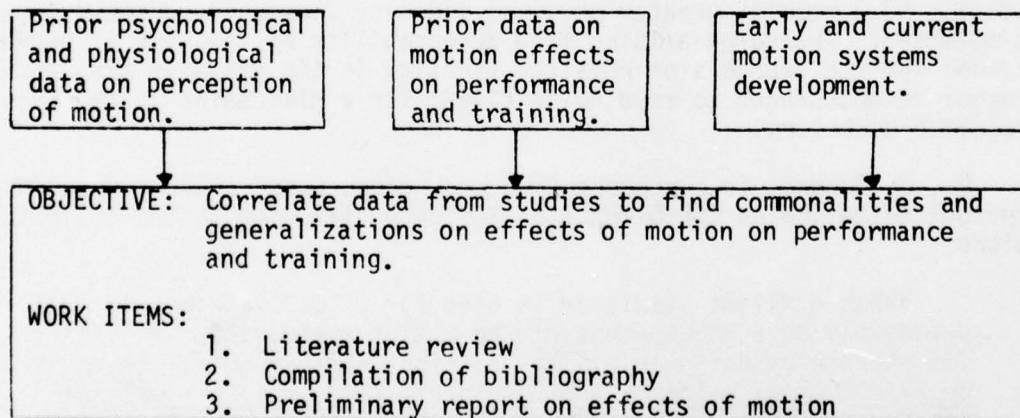
PURPOSE

The purpose of reviewing these publications was twofold: (1) to provide background material for NAVTRAEQUIPCEN Project No. 7744 - Motion Drive Signals for Flight Simulators and (2) to attempt to determine the consensus regarding the various questions concerning justification for including or excluding platform motion in simulators designed for flight training or research. In considering the latter, perhaps the best way to approach this question is to consider the main issue as the generation of proper motion cues to teach specific training objectives rather than simply proposing to include or exclude motion.

This review has also been an attempt to categorize studies formerly conducted concerning these questions and determine the direction in which results point. Unfortunately, most questions pertaining to the necessity for including platform motion in simulation do not have simple answers since most matters relating to this topic are complex.

APPROACH

The approach taken is shown diagrammatically below:



It seemed like a worthwhile effort to gather as much information, both objective and subjective, on the problem of motion simulation as was available at this time and to take another look at what the consensus tells us. As in so many other controversial issues in science, the truth probably lies somewhere in the middle, rather than at either extreme. It is not a matter of all or none. The need for motion appears to be task specific. It may be required

in order to train certain tasks but may not be required for others. A related matter concerns how the motion is simulated. A G-seat and simple buffet mechanism may suffice in many simulations. As Oscar Wilde said, "The truth is never simple, and rarely pure."

Another very practical question concerns the economics of the training program. Are the advantages of simulated motion in a specific case sufficient to justify a large economic burden, or will these advantages be nullified within the first few in-flight sessions?

Many studies have been criticized for lack of proper experimental controls or as being subjective; however, if we were to await the "perfect experiment" nothing would get done. In many cases, particularly in field studies, it was impractical to apply the controls which are possible in a laboratory setting. For this reason and at the risk of appearing unscientific, we included some studies based on quasi-experimental designs, some on nonexperimental designs, and some based solely on subjective opinion; accepting conclusions or attempting to draw conclusions despite the lack of experimental rigor.

One distinction that should be kept in mind when reviewing these reports is whether the application is towards engineering research or training. Although there are common factors in simulation to both of these areas, there are also important differences. Degree of realism is one difference. Research simulation is concerned with the broader aspects of new designs in an attempt to uncover and study previously unrecognized problems which have not yet been experienced in the operational situation -- problems which could lead to disastrous results if they were not accounted for in the design of the aircraft. The training simulator, on the other hand, attempts to reproduce the essence of situations that a pilot currently experiences in the operational environment. Generally, this means that the flight training simulator concerns itself with the fine details of recognized tasks, whereas research simulators are concerned with the broader aspects of new designs (Harper, 1964). As a result, greater physical fidelity is usually desired in training simulation. Pressures arising from acceptability by the user is another reason for the emphasis on physical fidelity in the training simulator. The reader is encouraged to read Rolfe (1968) for a discussion on the training/research dichotomy.

Dr. J. Gundry, in his paper "Man and Motion Cues" (1976), described the current situation on the effects of motion on training in the following quotations:

"When a flight simulator is used for pilot training, it must presumably be a requirement of the motion system that it justify its expense by being an aid to training. Unfortunately there is no experimental evidence that the presence of flight simulator motion aids training. In the following paper, much will be said about the effects of simulator motion on pilot performance. It will be shown that the presence of simulator motion has a beneficial effect upon pilot performance. Yet it must be remembered that pilot performance is not synonymous with pilot training. Performance is measured by errors and control activity observed in a simulator, whereas pilot training is measured by the number of aircraft hours that can be replaced by simulator hours in order

to give equal proficiency in flight. Whether a pilot performs better or worse in a simulator as a result of motion cues being present is of little consequence to him or the training organization if there is no effect upon his training. However, performance and control activity differences with and without motion are of great interest to psychologists and engineers, and this paper will review some of the evidence on this topic. By analysing the effects that motion cues have on performance, it is possible to offer some recommendations about procedures for determining the quality of motion cues that need to be provided in simulators used for routine training." (Underlining ours.)

Some confusion may arise, however, from the statement that, "...there is no experimental evidence that the presence of flight simulation motion aids training." Dr. Gundry apparently uses transfer of training to the operational situation as his criterion. Admittedly, the most definitive answers to the training effectiveness question are obtainable via the transfer of training model. The problems of control and implementation, however, are particularly difficult at this level of evaluation, and in training of emergency procedures would constitute a safety hazard.

Despite some shortcomings when compared to the transfer method, there are several other approaches to training evaluations. In these approaches, learning may be demonstrated through measured performance improvement in the same simulator, or comparative evaluation of different devices, or training programs. This type of experimentation has the advantage of being practical when conditions, such as safety considerations in emergency procedures, prevent true transfer of training experimentation. An example is a study conducted to evaluate the use of visual and motion cues on engine failure training in the KC-135 Aircraft (DeBerg et al, 1976). Another problem area in transfer experiments is that of measurement. It is difficult enough to take appropriate measurements in the simulator, but additional difficulties arise in taking comparable measurements in the operational situation.

Performance in the simulator may be useful as an indicator of training effectiveness if the training program has been designed with the training objectives clearly stated and measurement criteria clearly related to these objectives. Another requirement is that pilot control behavior be monitored. It is not sufficient to monitor system performance, as pilots can readily adapt their control activities to compensate for simulator inadequacies and produce the desired system output. Dr. Gundry alludes to using evidence based on performance as an indicator of training effectiveness in the last sentence of the paragraph quoted above when he states:

"By analysing the effects that motion cues have on performance, it is possible to offer some recommendations about procedures for determining the quality of motion cues that need to be provided in simulators used for routine training." (Underlining ours.)

The question of experimental evidence that the presence of flight simulation motion aids training is, then, dependent upon the rigor and level of the experimental design that the researcher is willing to accept. If operator performance improvement in the simulator is acceptable, there is evidence

both pro and con on this issue. The reader is referred to Section VI for a discussion on several studies concerning the effects of motion.

ORGANIZATION OF THE REPORT. There are nine sections to this report, including this introduction. Sections II through IX discuss the categories of the annotated references as listed in the Table of Contents. So as not to interrupt the continuity of the text, all tables and listings are included at the end of the report. Tables 1 through 7 appear immediately after Section IX and are followed by Appendix A, the listing by categories, Appendix B, the chronological listing and, Appendix C, the alphabetical listing which contains the abstracts.

SECTION II

REVIEWS AND BIBLIOGRAPHIES

The differences of opinion as to whether motion is required for flight training has created an interest in experimental studies and review articles concerning this area of specialization. Most of these publications have been sponsored by the Department of Defense, the National Aeronautics and Space Administration, and the Advisory Group for Aerospace Research and Development of the North Atlantic Treaty Organization. These reviews and bibliographies have been grouped together in Appendix A.

Included among these publications is the hearing before the Subcommittee in Research and Development of the Committee on Armed Services, U.S. Senate 94th Congress, May 13, 1976. This publication presents an interesting backdrop for the motion/no motion controversy and, as stated by Senator Barry Goldwater in the opening statement, is unique in being the first hearing directed exclusively to flight simulators.

SECTION III

EQUIPMENT DESCRIPTIONS

Cockpit motion hardware equipment descriptions are frequently found in the literature. Often the descriptions are of research tools used either for aircraft development or in training research. A logical grouping of the facilities descriptions may be accomplished by categorizing the descriptions by research organizations. For example, NASA Ames Research Center, has had its equipment described, in general, by several authors: Dusterberry and Barnett (1963) and Rathert (1970). The Flight Simulator for Advanced Aircraft (FSAA) is described by Bray (1971), Bray (1972) and Zuccaro (1970). Their centrifuge is described by Sadoff (1962) and Johnson (1963). Description sheets were prepared in 1970 which outline features, performance specifications and the limitations of the NASA Ames flight simulators.

NASA, Langley Research Center, has had its equipment described in general terms by Phillips, Queijo and Adams (1963) and Stitt (1977). Ashworth and Kahlbaum (1973) described the Differential Maneuvering Simulator and its buffet mechanism. Ashworth and Parrish (1976) describe their general aviation simulator and changes made to its cockpit motion drive model. Brown and Johnson (1959) described the Normal Acceleration and Pitch Simulator. Eldridge and Crane (1966) provided information on the simulation used for the Supersonic Transport.

The US Navy has been well represented by the Naval Air Development Center and the centrifuge simulations which were performed there. Brown (1959), Brown, Keuhnel, Nicholson and Futterweit (1960), Clark and Woodling (1959), Crosbie (1956), Chambers and Nelson (1963), Hardy and Clark (1959), Hitchcock (1964) all provide descriptions of various simulations ranging from turbulence to the X-15 aircraft. Browning, Ryan, Scott and Smode (1977) provide some description of the P3-C simulator on which they were conducting transfer of training studies. Wampner (1971) reported the capabilities and requirements of motion simulation systems which had been procured by the Naval Training Equipment Center at that time.

The Air Force too is well represented in describing their simulation equipment. Westbrook (1964), provided a review of their piloted simulation facilities, classified, discussed how and why the facilities were needed and came to be, and were used. Valverde (1968) reviewed simulator R&D that was sponsored by the US Governmental agencies. His topics include visual and motion, transfer of training utilization and evaluation. Dunlap and Anderson (1974) and Dunlap and Worthey (1975) presented USAF master plans for simulators. Hyde (1963) and Goltra and Hyde (1965) discuss centrifuge simulation equipment. Gum and Alberty (1976) and Matheny, Gray and Walters (1975) discuss the Advanced Simulator for Pilot Training and some of the problems encountered with integrating its visual and motion simulations. Haas, Holtz and Mills (1973) discuss the Large Amplitude Multi-mode Aerospace Research (LAMAR) Simulator manufactured by Northrop for the Flight Dynamics Laboratory.

Several commercial firms have published the performance capabilities of their cockpit motion hardware. The Franklin Institute system and others were discussed by Bell personnel (Anon 1960), Hackler (1960), and Sgro and Dougherty (1963). Kennelly (1959) described a Grumman research simulator,

and Gallagher and Nelson (1973) described the Northrop Large Amplitude three axis flight simulator. Sylvania provided a description (Anon 1963) of the Universal Digital Operational Flight Trainer in 1963. The SAE surveyed the R&D simulators in use in 1964 and published (Anon 1964) a summary. Chalk and Wasserman (1976) of the Calspan Corporation published an additional survey of needs, requirements and equipment used in a report for the Office of the Assistant Secretary of Defense. Kelly (1970) published an interesting history of simulation (and motion issues) in general, and the Link Company in particular. The B-58 trainer motion system was described by Miller (1960), and the B-747 trainer motion system was described in Aviation Week and Space Technology (1968) by Stein.

Perhaps the most succinct of all the equipment descriptions appeared in ASRO Report 75-1 (Burke et al., 1975). All the R&D simulators in use in industry and the various governmental agencies were summarized in tabular format and are reproduced here as Tables 1 and 2 for the reader's convenience. An amendment has been made to include the Naval Training Equipment Center's new research tool, the Aviation Wide-Angle Visual System (AWAVS) cockpit motion base description.

Our European colleagues have provided many descriptions of the cockpit motion hardware in use in their R&D activities. Kidd, Bull and Harper (1961), Harper (1964), and Quigley (1964) detailed the capabilities of the AGARD Research simulators then in use. Davis and Beadsmoore (1970), Rolfe (1973), and Edenborough (1968) discuss the new generation of simulators, the user opinion of simulators with and without cockpit motion in use in the RAF and the development of simulator hardware. Warton (1972) details some of the engineering and design considerations of control and safety with respect to the development of the RAE four degree-of-freedom cockpit motion base. The six degree-of-freedom Dynamic Manned Vehicle Simulator used by the British Aircraft Corporation was described in Aircraft Engineering (Anon, 1972).

Ruehamn (1975) describes a West German R&D cockpit motion simulator. The mechanical hydraulic and electrical components of the system are described fully. Koevermans and Jansen (1975) provide equipment and performance descriptions of the new four degree-of-freedom motion system in use at the Dutch National Aerospace Laboratory. The hardware is specialized in having very low-friction hydrostatic bearing surfaces resulting in extremely low noise and friction levels.

Force cueing devices of various types have been studied in an attempt to simulate sensations of accelerations in simulators without producing motion of the magnitude experienced in the operational situation. As it is introspectively difficult to distinguish vestibular from somesthetic sensations, this approach may offer a simplified and less expensive solution to the simulation of motion.

The G-seat concept of "dynamic seat," a term coined by Goodyear Aerospace Corporation (Barrett, Cabe, Thornton, and Kerber, 1969) is a device in this category which has received a great deal of attention within the past few years. The Air Force has developed G-seats with Singer-Link Division as subcontractor (Kron, Young, and Alberty, 1977; Alberty, Gum and Hunter, 1976). NASA, Langley has developed a simpler seat with faster response time (Ashworth, McKissick, and Martin, 1977). Some experimentation is being pursued

to determine if the G-seat can be used as a substitute for the larger, more complex motion platforms. For a comparison of the results of evaluative studies conducted on the G-seat, see Table 3.

During the early stages of development, the G-seat was envisioned as an inexpensive substitute for motion platforms, however, as the cost of motion platforms have decreased, the cost of G-seats have increased to the point where there is not much savings -- unless the simpler NASA Langley seat can be manufactured at a low cost and is shown to be effective in training. The Air Force also is giving consideration to the development of a second generation G-seat which will improve response time and provide a seat with both onset and sustained cueing capability at a lower cost than that of current G-seats (Albery, Gum, and Hunter, 1976).

Another force cueing device, originally designed to protect pilots from the effects of centrifugal force encountered in flight, is the G-suit, an automatically inflating pneumatic pressure suit (Mazer, 1945). Its use has been reported to provide essential sustained cues during simulation of high G maneuvering (Hutton et al., 1976).

Some early work done in the field of "force cueing" is described by Christensen and Johnson (1958). Their study, concerned with means of producing simulated forces, was divided into four main categories: (1) hydraulic and pneumatic transducers, (2) heavy fluids, (3) electrical stimulation, and (4) electromagnetic systems.

PATENTS

The evolution of cockpit motion hardware may best be traced through the offices of the U.S. Patent Office and the patent offices of foreign countries. Many unique and interesting schemes have been used in the past for training aviators better. It appears that some type of cockpit motion was usually deemed necessary by the training community and the inventors of the training equipment. Many of the early patents described a collection of multipurpose hardware which could be used either as an aviation training device or as an amusement park entertainment apparatus. Two of the earliest training tools, "The Sanders' Teacher" and "The Eardly-Billing Oscillator," were built around 1910. They were not commercially successful; however, and it was not until 1929 that the first "successful" trainer, patented by Ed Link (PN 1,825,462-1931), was placed in use. Figure 1 depicts this famous patent.

Two early European patents were issued to Lender and Heidelberg (PN 13,332 and PN 127,820) around 1918. They described a device (Figure 2), designed to train aviators, which had a cockpit motion system and many variations in its implementation. Most interesting was the use of pneumatic cylinders to effect the motion; however, hydraulics and articulated beams were also mentioned as alternative motion producing techniques.

Two patents were issued to W. G. Ruggles (Figure 3) for his aviation training devices known as "orientators" (PN 1,342,871--1920 and PN 1,393,456-1921). A. Bisch (PN 1,791,655-1931) was so strongly of the opinion that motion cueing was important that he mounted a scaled-down aircraft on a tether and boom arrangement and pulled the aircraft through the sky to provide that cueing. Figure 4 depicts this interesting motion producing device.

Sept. 29, 1931.

E. A. LINK, JR.
COMBINATION TRAINING DEVICE FOR STUDENT
AVIATORS AND ENTERTAINMENT APPARATUS
Filed March 12, 1930

1,825,462

4 Sheets—Sheet 1

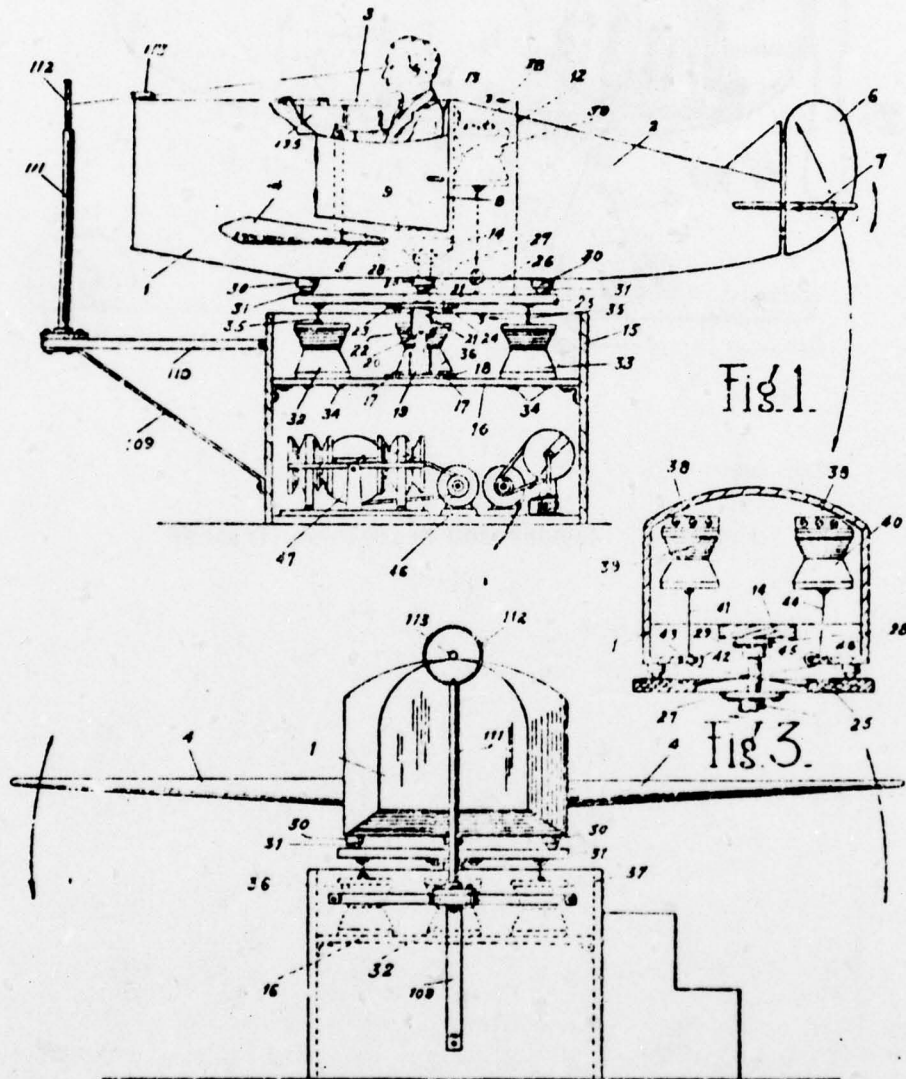


Fig. 2.

INVENTOR
EDWIN A. LINK, JR.
BY *Philip S. Stephens*
ATTORNEY

Figure 1. Early Link Trainer

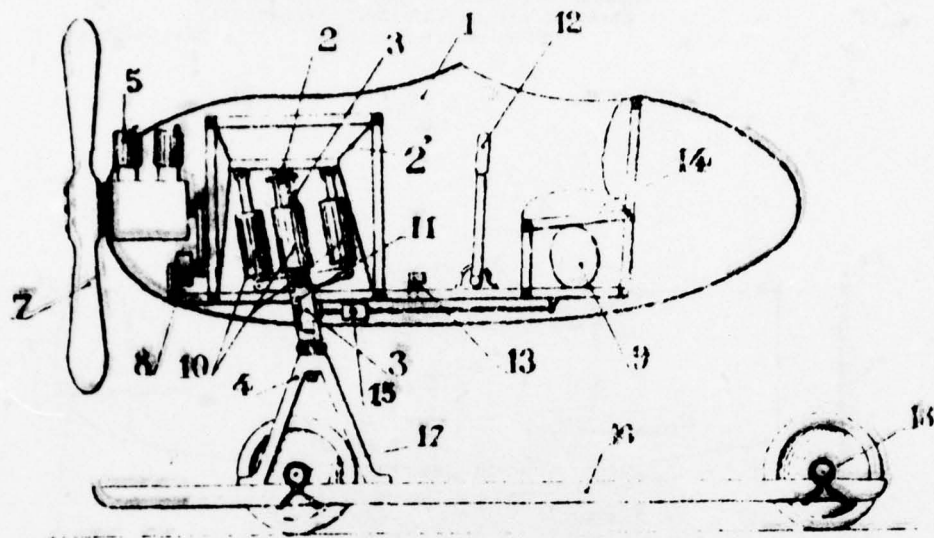


Figure 2. Lender and Heidelberg Trainer

NAVTRAEQUIPCEN IH-298

W. G. RUGGLES.
ORIENTATOR.

APPLICATION FILED SEPT. 7, 1918.

Patented Oct. 11, 1921.

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1,393,456.

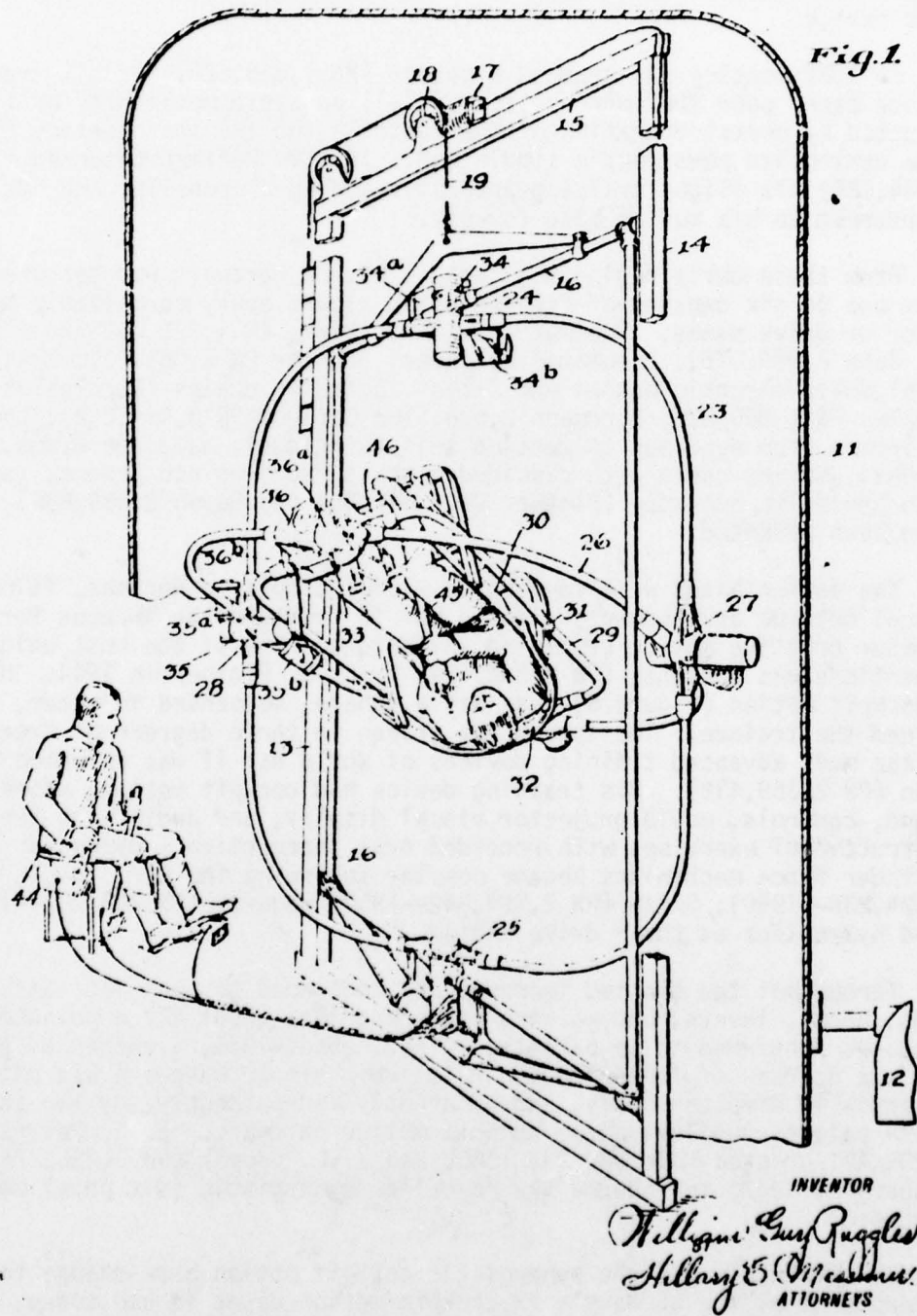


Figure 3. Ruggles Orientator

In 1931 J. E. Gwinnett was granted a patent (PN 1,789,680) for a moving platform on which perhaps 100 persons could be simultaneously moved. See Figure 5. The intent was to move the platform synchronously with a visual display to enhance the realism. To carry the theme slightly further, wind, smoke, sound, odors and temperature changes were claimed for this mass amusement device.

In 1932 Buckley was granted a patent (PN 1,865,828) for his training device based upon the introduction of "all possible movements" of the aircraft actuated by normal operation of the controls and the introduction of paper tape controlled atmospheric simulation. In 1934 Huffman patented (PN 1,944,180) his flight training apparatus adding a propellor and its associated slipstream to his moving base cockpit.

From these early beginnings cockpit motion hardware was designed to provide from one to six degrees-of-freedom using almost every conceivable type of power or drive means. Pneumatic bellows (Link, PN 1,825,462 and 2,099,857; St. John 2,369,418); Pneumatic cylinders (Custer PN 2,063,231; Koci PN 2,661,954); electric motors and cables, belts or chains (Ruggles PN 1,342,871; Buckley PN 1,865,828; Herrmann 2,528,516, Carlyon PN 3,494,052); hydraulic cylinders (too numerous to mention this technique); balanced beams, movable weights, moving carts with cascaded gimbals, springs and levers, centrifuges even hydraulic buoyancy (Plotner PN 2,344,454 and Guyon 3,559,936) techniques have been patented.

The motion bases were coupled to visual display panoramas, films and actual outside environments. World War II provided the impetus for still further creative motion producing inventions. One of the most unique of these inventions was patented (PN 2,344,454) by L. D. Plotner in 1944. His idea of a cockpit motion (Figure 6) base was a sphere, suspended in water, which contained the trainee. The sphere was driven in three degrees of freedom. One of the most advanced training devices of World War II was patented by E. St. John (PN 2,369,418). His training device had cockpit motion, coordinated sound, controls, movie projector visual display, and audio with progressive instructional exercises with recorded oral instruction. Hydraulic power cylinder force mechanisms became popular following the war. Soule (PN 2,524,238--1950); Smith (PN 2,787,842--1957); Fogarty (PN 2,930,144) and others used hydraulics as their drive medium.

Throughout the sixties improvements continued to be made. Cascaded gimbals, beams, levers, and walking beams and just about all combinations of linkages continued to be patented. Then, about 1965, a method of producing all six degrees of freedom using relatively simple hardware was patented, essentially simultaneously, and apparently independently, by two inventors. These patents revolutionized cockpit motion hardware. E. R. Peterson (PN 3,288,421 granted November 29, 1966) and K. L. Cappel (PN 3,295,224 granted January 3, 1967) introduced the so-called synergistic (six post) motion hardware.

So completely did the synergistic cockpit motion base change the hardware makeup that of the US Navy's 73 cockpit motion bases in use today, approximately 50 are of the synergistic type. Today nearly all simulator manufacturers will use a synergistic motion base with their simulators. Figures 7 and 8

Feb. 10, 1931.

A. BISCH

1,791,655

AIR PILOT TRAINING DEVICE AND THE LIKE

Filed Dec. 5, 1929

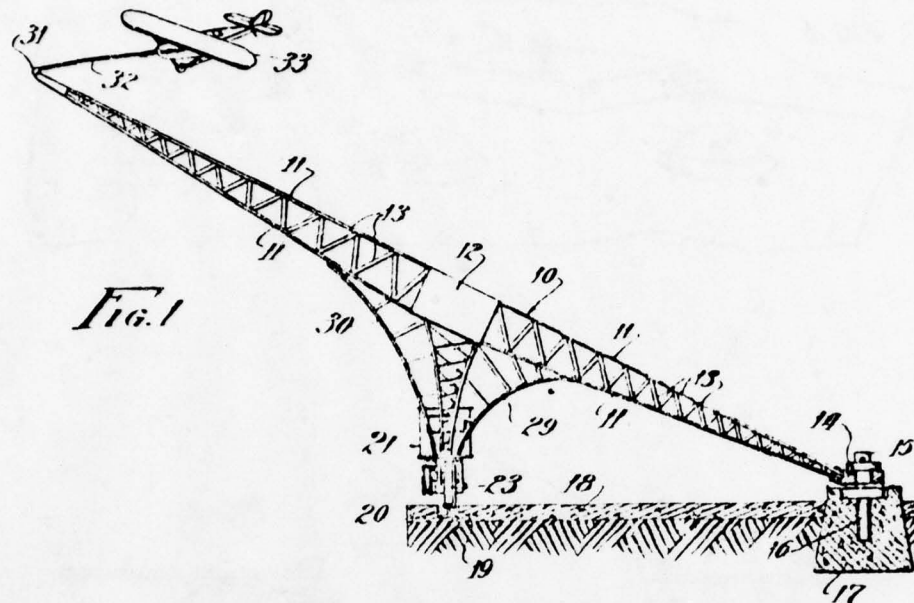


Figure 4. Bisch Trainer

Jan. 20, 1931

J. E. GWINNETT

1,789,680

AMUSEMENT DEVICE

Filed Oct. 1, 1928

2 Sheets-Sheet 1

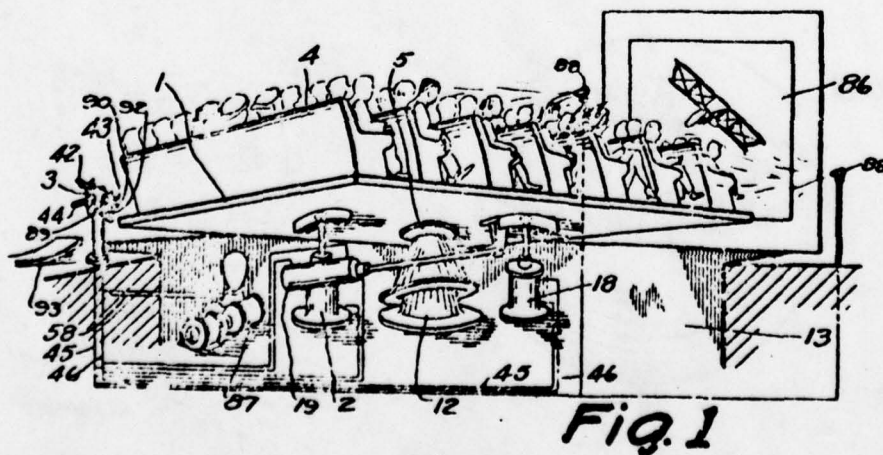


Figure 5. Gwinnett Moving Platform

March 14, 1944.

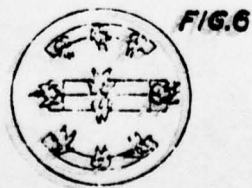
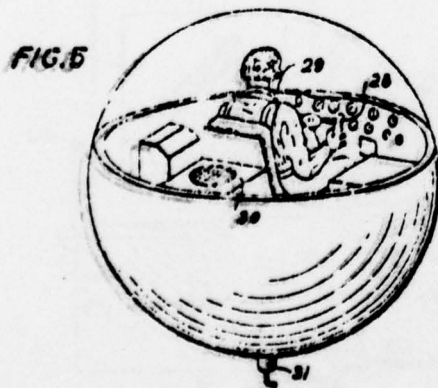
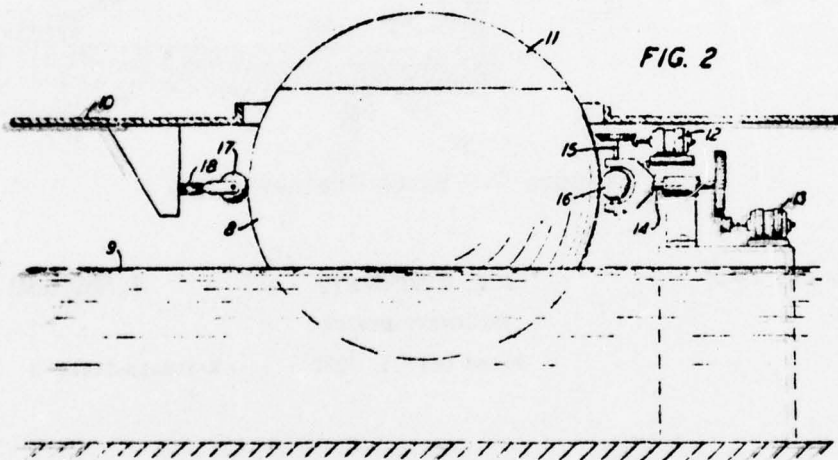
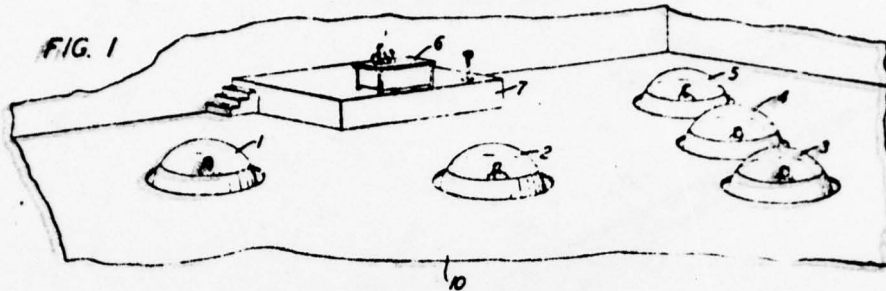
L. D. PLOTNER

2,344,454

TRAINING DEVICE

Filed Dec. 7, 1942

2 Sheets-Sheet 1



INVENTOR
L. D. PLOTNER
BY *John A. Hall*
ATTORNEY

Figure 6. Plotner Trainer

Nov. 29, 1966

E. R. PETERSON

3,288,421

MOVABLE AND ROTATABLE TOP

Filed March 29, 1965

3 Sheets-Sheet 1

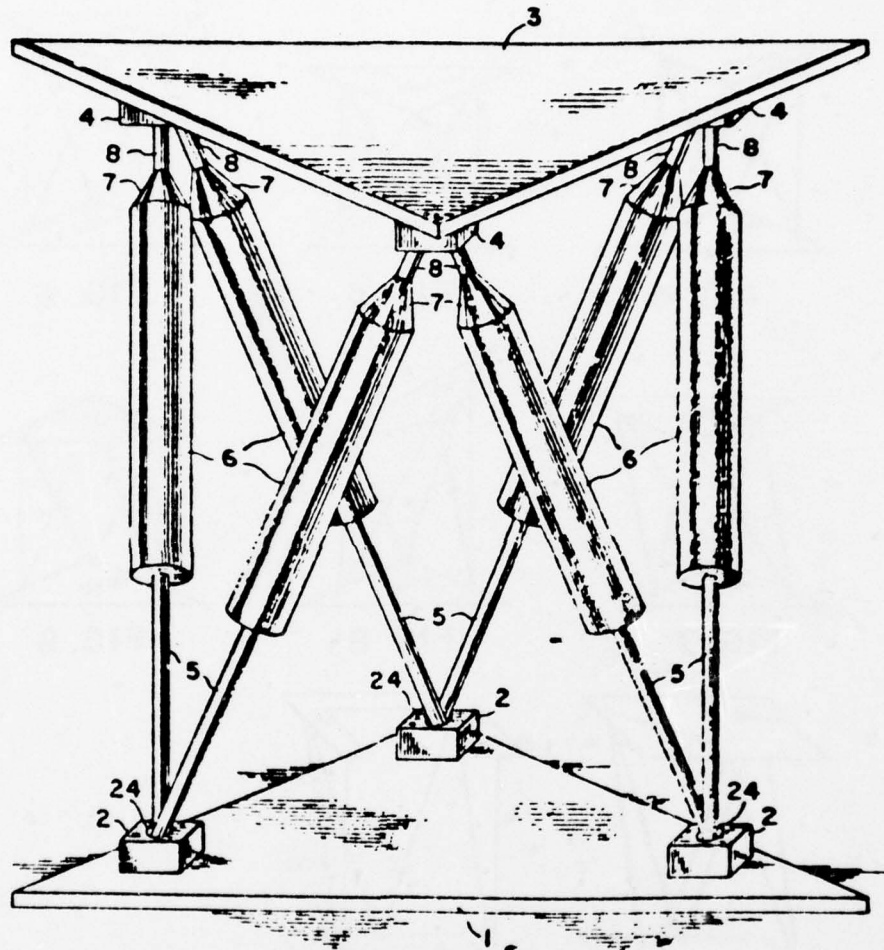


Figure 7. Peterson's Motion Base (Configuration)

Nov. 29, 1966

E. R. PETERSON

3,288,421

MOVABLE AND ROTATABLE TOP

Filed March 29, 1965

3 Sheets-Sheet 3

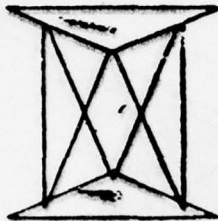


FIG. 4

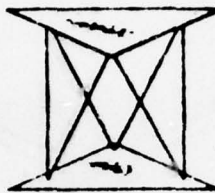


FIG. 5

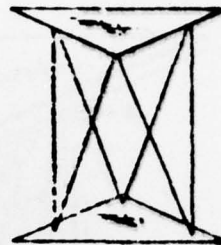


FIG. 6

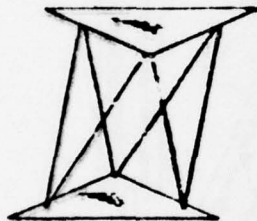


FIG. 7

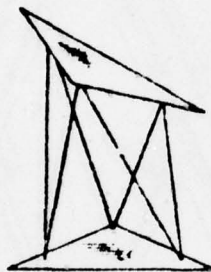


FIG. 8

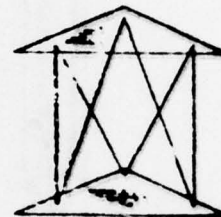


FIG. 9

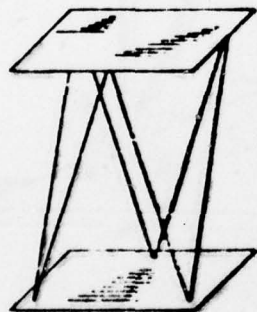


FIG. 10

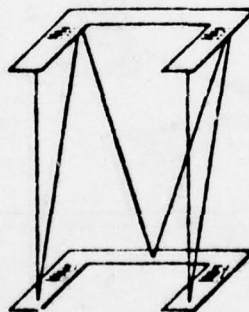


FIG. 11

Figure 8. Peterson's Motion Base (Positions)

were taken directly from Peterson's patent and Figures 9 and 10 were taken from Cappel's patent.

In summary, our patent search revealed an interesting history of the development of cockpit motion hardware which is not over. Akister, Shelley and Heath were granted a patent (PN 3,597,857) in 1971 for yet another configuration of hardware. Curiously, the only major type of hardware not uncovered in our search was the articulated beam or boom type of research motion base manufactured by Northrop. The Ling-Temco-Vought type of boom system was patented (PN 3,883,473) by W. B. Luton in 1963.

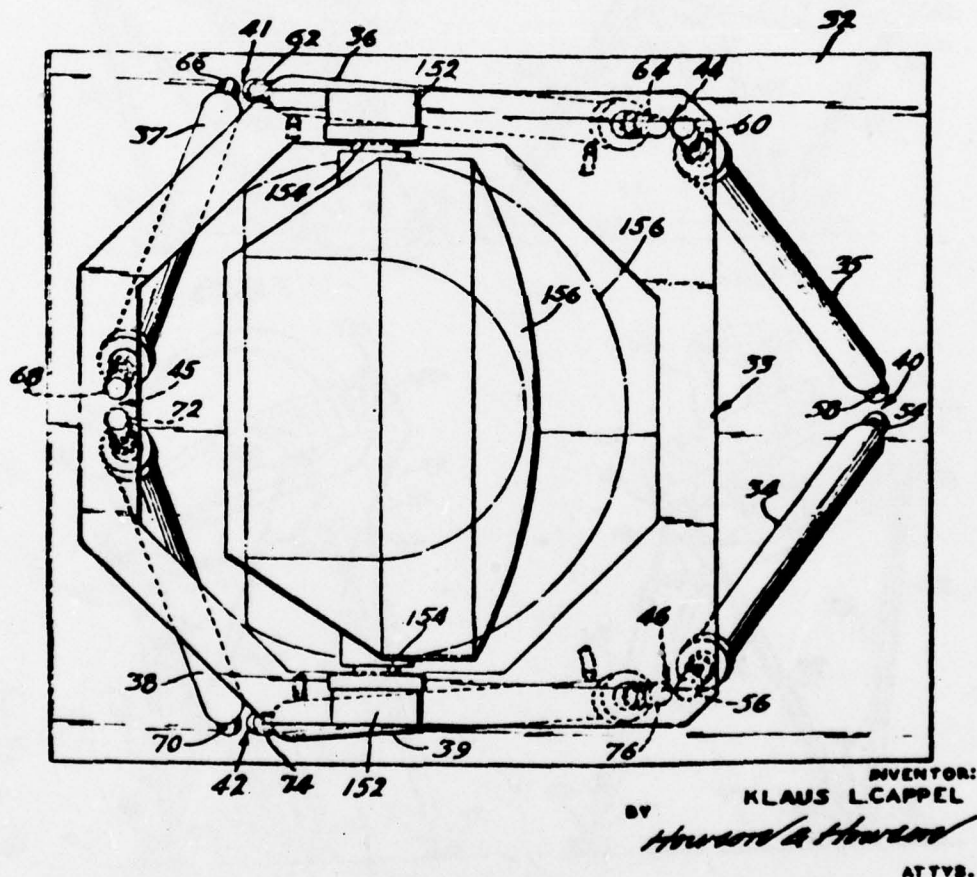


Figure 9. Cappel's Motion Simulator (Configuration)

Jan. 3, 1967

K. L. CAPPEL
MOTION SIMULATOR

3,295,224

Filed Dec. 7, 1964

6 Sheets-Sheet 6

FIG. 10.

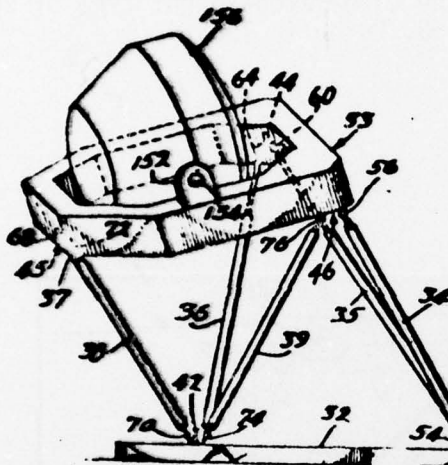


FIG. 12.

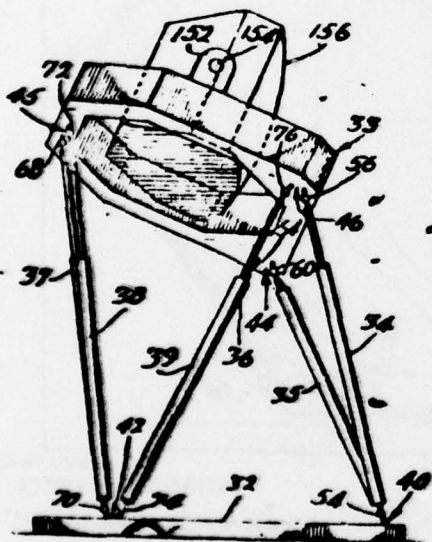


FIG. 11.

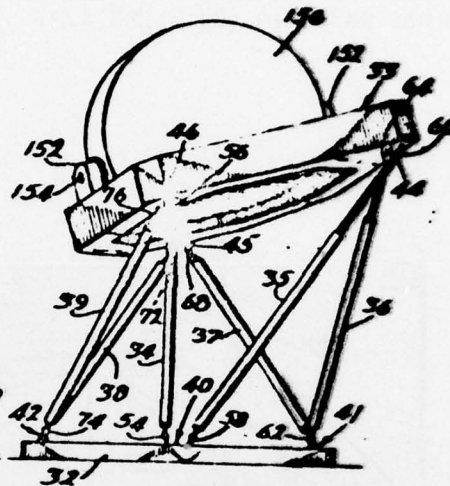


FIG. 13.

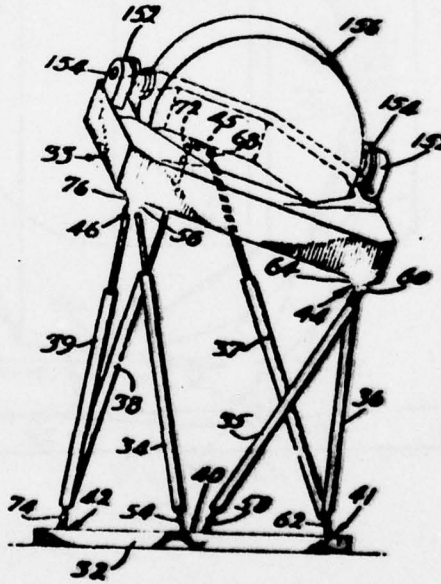


Figure 10. Cappel's Motion Simulator (Positions)

SECTION IV

REQUIREMENTS

After reviewing the rather large body of literature available in the motion/no motion controversy, it appears that one can divide the opinions into three fundamental categories: those who see some benefit in utilizing cockpit motion, those who see no training benefit, and those who are uncertain as to the effects of cockpit motion cueing. The literature, which was examined during this literature survey, has been categorized in Tables 4, 5 and 6 and selected comments appear with each cited reference. The largest portion of the reviewed literature, prior to 1974 publication, was pro-motion cueing (Table 4), with considerable discussion as to which degrees of freedom were of importance. That particular issue seems to be a function of the aircraft type being simulated and assigned training task. In any case, the degrees-of-freedom issue is likely to be a moot point in that there exist six degree-of-freedom synergistic systems whose cost (\$150K) is less than that of four (\$260K) and five (\$285K) degree-of-freedom systems. This cost (\$150K) is approximately equal to the cost of some of the G-seat cueing devices being procured* today.

Cockpit motion cueing has been used in flight simulators since the earliest aviator training devices were conceived (see the section on patents in this report). It is recognized by simulation personnel that, due to physical limitations and size constraints, the engineering community cannot construct motion bases which can duplicate the forces and velocities incurred in actual flight, for more than a brief period of time. It is further recognized that, depending upon the hardware and software combinations used to provide the cockpit motion cueing, the proper cues are often accompanied by spurious cues due to system noise, algorithm, excursion and velocity limiting, or misalignment of the gravity vector. Allowing all these constraints, until the mid-1970's the question asked most often was not "Is cockpit motion cueing required for training?" but rather "How much cockpit motion cueing, and of what kind is required for training?" A vast amount of the literature is devoted to stipulating the beneficial effects of including cockpit motion cueing in both research and training simulators. Graham (1968) presents an extremely convincing collection of references and arguments which are clearly in favor of including cockpit motion cueing in research simulators. He goes on to point out, "Thus, adequate simulation of turbulent flight for both research, development, and training purposes is considered vital." With respect to coordinated motion cueing (motion resulting from pilot control activity or wind phenomena other than randomized rough air), Graham points out, "Once a pilot becomes familiar with his aircraft, the motion information he receives during flight by way of vestibular, proprioceptive, and tactile cues provides him either reassuring feedback that all is well or early warning that something is wrong." Other interesting points Graham brings out include the following. Motion cues are effective because: humans do not sense acceleration well visually; acceleration is the time derivative of velocity, hence it predicts changes in velocity; a pilot's sensory mechanism need not be directed since it is always activated. "Several experimental studies (Huddleston, 1966; Newton, 1959; Young, 1967) have noted that physical motion in simulation degrades the performance of inexperienced subjects but improves the

*All costs are in 1976 dollars.

performance of experienced pilots." Graham further presents the argument that if advanced pilot training is conducted on a fixed-base simulator, inappropriate behavior will be learned because omitting motion cues forces a pilot to change his behavior (to watch the primary signal more closely, to use larger, less frequent control movements and to permit greater errors).

Smode (1971) provides a brief summary of pertinent literature with the view of answering two significant questions; "(1) does moving base simulation facilitate training, and (2) if the addition of motion provides training advantage, how and to what extent is this advantage manifested?" Smode reports, "The research findings suggest that motion cues: (1) serve to alert the pilot to changing states, (2) encourage the buildup of correct habit patterns in training, (3) increase the realism of the simulation thereby enhancing trainee confidence in the device, (4) improve pilot responses, (5) affect aircraft control tasks, (6) are differentially useful as a function of the skill level of the pilot, and (7) vary in relevance (parameters and values) as a function of task or mission requirements.

Gundry (1975) summarized the literature in a few sentences which are paraphrased herein: "A number of authors believe a cockpit motion system is necessary (Borlace, 1967; Cohen, 1971; Frazer, 1966; Gibino, 1968; Graham, 1968; Huddleston, 1966; Huddleston and Rolfe, 1971; Staples, 1970). This conclusion is based upon three consistent research findings:

a. Pilots perform better in a moving simulator than they do in a static simulator (Besco, 1961; Bray, 1973; Brown, Kuehnelt, Nicholson and Futterweit, 1960; Buckout, Sherman, Goldsmith and Vitale, 1963; Gerathewohl, 1969; Goldsmith, Sherman and Vitale, 1961; Matheny, Dougherty and Willis, 1963; Ruocco, Vitale and Benfari, 1965; Sadoff and Harper, 1962).

b. The pattern of pilots' control activity in an aircraft is more closely approximated by control activity in a moving rather than a static simulator (Greer, Stewart, Merrick and Drinkwater, 1959; Douvillier, Turner, McLean and Heinle, 1960; Fedderson, 1962; Rolfe, Hammerton-Fraser, Poulter and Smith, 1968; Ragland, Chambers, Crosbie and Hitchcock, 1964; Sadoff, McFadden and Heinle, 1961, Tremblay, Brown and Futterweit, 1964).

c. Instruments and displays are evaluated differently in moving and static simulators (Matheny, Dougherty and Willis, 1963; Douvillier, Turner, McLean and Heinle, 1960; Jacobs, Williges and Roscoe, 1973; Rathert, Greer and Douvillier, 1959).

However, some authors have recently doubted the value of motion in flight simulators used for training (Jacobs, Williges and Roscoe, 1973; Hopkins, 1974; Williges, Roscoe and Williges, 1973).

There has been no experiment designed specifically to assess the effect of motion in determining the transfer-of-training from a simulator to an aircraft. This is an important omission in the research history of flight simulation, for it matters little how well or realistically a pilot behaves in a moving as opposed to a static simulator, if experience in the simulator does not lead to more effective training.

The "negative training value" group of literature (Table 5) is generally of more recent vintage, and can be traced to transfer of training studies conducted by the Air Force Human Resources Laboratory at their Williams Air Force Base Advanced Simulator for Pilot Training (ASPT) research facility, and studies conducted at the University of Illinois, Institute of Aviation.

The experimental work conducted at ASPT appears to be well designed, executed and analyzed. The experiments are true transfer of training studies generally using student pilots. The studies cover a variety of piloting tasks from basic contact landing and approach (Martin and Waag, 1978), air-to-ground weapon delivery (Gray and Fuller, 1977) and a series of contact maneuvers (Irish and Buckland, 1978). In general, pilot performance is reported to be no better with the cockpit motion operational than with it deactivated.

Another group of "negative" or "questionable" training value reports focuses upon the work performed by Dr. Koonce. His work was directed not toward transfer of training but at establishing the predictive value of simulator training. He concluded: "...that the sustained motion resulted in higher predictive validities than the no motion or washout-type motion systems; and there were no significant differences between these later two motion systems in the predictive validities of the individual maneuvers... but the differential effects of motion on the simulator performance does not transfer to the performance in the aircraft."

Roscoe (1974) and Hopkins (1974) interpreted Koonce's data as evidence that the presence or absence of motion makes no difference to the transfer of training obtained during simulator training. However, discrepancies in the interpretations of Koonce's study by Roscoe and by Hopkins were pointed out by Gundry (1975) in which he states, "...that the design of Koonce's experiment does not allow this conclusion to be drawn, since there is no evidence that training occurred."

Thus, it appears that the training community is presented with two diametrically opposed points of view with respect to the training enhancement value of cockpit motion cueing. A very logical question now appears. Is it possible that both points of view can be equally valid? That is, have all the researchers, who have published their findings, had properly constructed experiments, and have they correctly deduced conclusions from the experimental data? The answer to this important question may be, yes. An explanation is in order. It may be that any of the following categorical reasons could satisfactorily explain the disparity of results:

- a. Nature of the cueing being submitted to the experimental subjects.
- b. Nature of the visual motion interaction used during the research.
- c. Nature of the study undertaken.

Each of the areas will now be further discussed. Consider the first category.

THE NATURE OF THE CUEING BEING SUBMITTED TO THE EXPERIMENTAL SUBJECTS

This area contains many variables which unfortunately are very rarely published along with the experiments which are being published/presented. It is clear that the type of cueing a subject receives is a function of at least the following variables.

THE CAPABILITY OF THE HARDWARE WHICH WAS USED IN CONDUCTING THE EXPERIMENT. Here, we mean the actual physical performance capability of the hardware. What are the limits of excursion, velocity and acceleration? Are these limits large enough to impart other than a disturbance cue? What is the frequency capability of the hardware in each degree of freedom? Is the hardware functioning normally, i.e., were daily readiness checks performed to assure normal hardware performance during the experiment? Is the hardware equipped with filters which can reduce the performance of which the hardware is capable? As an example, one major supplier of cockpit motion hardware normally equips his analog hardware with classical second-order, low-pass filters of three radians per second natural frequency. The effect of these filters is to introduce a ninety degree phase lag (the output of the filter lags the input to the filter) at approximately one-half Hertz. At the short period frequency of many of the military trainers and fighters, etc. (approximately seven tenths of a Hertz), the phase lag can be 100° to 120° . NASA Langley has published this problem and their solution as NASA TN-7349, Parrish, Dieudonne, Martin and Copeland (1973).

THE NATURE OF THE COMMANDS FED FROM THE DIGITAL COMPUTER TO THE ANALOG CIRCUITRY OF THE MOTION BASE. As long as the physical hardware performance of the motion equipment is not being exceeded, the cockpit motion will track the signals which are being used to drive the system. Two areas of importance stand out as worthy of note. The first is that the iteration rate of the equations being used to provide the flight simulation (equations of motion or flight equations) and the iteration rate of the cockpit motion drive philosophy used (more on this later) are of critical importance. For example, if the cockpit motion drive equations are being computed at 20 times per second (a common value), then a serial or pipe-line delay of fifty milliseconds is experienced before the analog hardware even receives its input signal. An iteration rate of ten times per second causes a pipe-line delay of 100 milliseconds, an iteration rate of seven and one-half causes a pipe-line delay of 133 milliseconds, and so on, required just for the results of the calculation of the motion drive equation. Similar delays are experienced in calculating the flight equations whose output constitutes the input to the motion drive equations. NASA Langley updates all of their equations at 32 Hertz in order to minimize this pipe-line delay. The personnel at Northrop are experimenting with iteration rates of 50 Hertz to determine the effects of this delay.

The second major area of importance in this section dealing with drive commands involves the algorithms or philosophy used in the cockpit motion driving commands. It must be recognized that it is impossible to use the outputs of the flight equations directly as drive signals for the motion base. Obviously the motion base can only maintain linear and angular accelerations for brief periods of time before structural limitations are reached either in acceleration, velocity or excursion. Hence, some sort of drive philosophy

and its associated algorithms must be used. The inputs to these motion equations usually are simulated aircraft linear accelerations and angular accelerations, velocities and position. In the various algorithms published in the literature, many combinations have been identified. Odierna (1970) and Hayden (1970) summarized them. We quote Odierna (1970) below:

"The six basic concepts:

(1) The proportional concept - The magnitude of the motion system acceleration is always proportional to the magnitude of the aircraft acceleration.

(2) The clipped magnitude concept - The magnitude of the motion system acceleration cannot exceed a set limit.

(3) The clipped slope concept - The slope of the magnitude of the motion system acceleration cannot exceed a set limit.

(4) The mixed concept - Any combination of the concepts, (1), (2), (3) above.

(5) Transfer function onset and washout concept* - The magnitude of the motion system acceleration and phase is determined by shaping filter techniques, i.e., aircraft acceleration subjected to a predetermined transfer function.

(6) The aircraft acceleration concept - The magnitude of the motion system acceleration is equal to the magnitude of the aircraft acceleration.

A ground-based motion system that would successfully utilize the last onset drive signal philosophy, i.e., (6), cannot be built, and will be discarded from further consideration."

Figure 11 depicts these general algorithm categories.

It should be further mentioned that many of the concepts mentioned are also applied to velocity or positional variables as well as the acceleration. For example, the proportional concept is often applied, in smaller motion bases, to the positional variables for the angular degrees of freedom, i.e., the simulator cockpit will pitch (or roll) an amount proportional to the amount the simulated aircraft has pitched (or rolled). The transfer function concept appears in practice in many different forms. Commonly encountered forms of transfer function include:

a. Low pass filters of 1st, 2nd, 3rd and 4th order.

* A washout concept is defined as the methodology in determining the motion of the simulator cockpit in order to washout the results of the onset cue, i.e., the velocity and position change, at subthreshold levels to allow the motion system to either return to the neutral position or a position such that the gravity vector is substituted for sustained linear acceleration (gravity align).

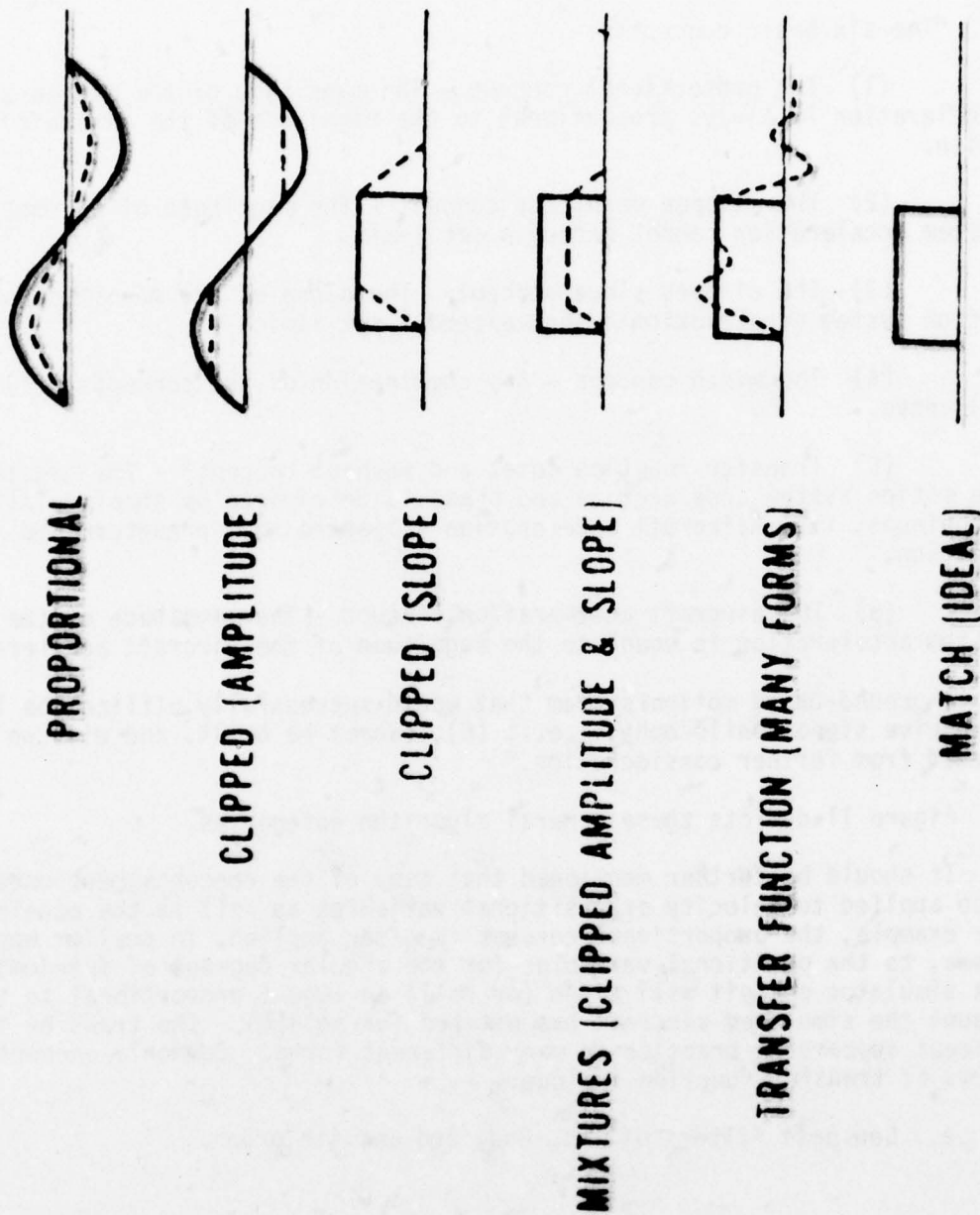


Figure 11. Algorithm Types

- b. Band pass filters of 2nd, 3rd and 4th order.
- c. High-pass filters of 1st, 2nd, 3rd and 4th order.

It must be emphasized that once a transfer function form has been chosen, the filters may be applied to accelerations, velocities and positions and that a given transfer function can have infinitely many responses depending upon the gains, natural frequencies, and damping constants chosen for the filter. A more detailed discussion of the forms of transfer functions and the effects of these forms is to be published as NAVTRAEQUIPCEN IH-299.

The issue of the proper algorithm type is certainly not resolved if one considers the amount of work that has recently been performed by Parrish et al, at NASA Langley. They have used and evaluated the classical 2nd order wash-outs (filters) recommended by Schmidt and Conrad (1970) in coordinated coupling to allow gravity alignment as a cue for sustained accelerations and to remove spurious cues caused by simple rate matching, and uncoordinated forms. They further experimented with digital controller filters and cue generation via the steepest descent optimization. This last form appears to be the most encouraging. Sinacori (1977) reviewed selected literature with emphasis on the roll drive logic. He evaluated the effects of the various types of cue generation and drew implications for further research. Table 7 summarizes the relevant comments available which address preferred algorithm types. As incredible as it may be, there still does not exist a justification for a particular type of algorithm (and associated gain, frequency and damping coefficients) as a function of training value.

A final entry in the hardware capability section concerns the visual display capability utilized during the experiments. Many of the earlier works had no visual display (other than instruments); others had small CRT type displays; still others involved a television type display. Some were very narrow in field of view, others essentially duplicated that obtainable with the actual aircraft. Clearly, the nature of the visual stimuli could have affected the outcome of the experiments.

THE INTERACTION OF VISUAL AND MOTION CUES UTILIZED IN CONDUCTING THE RESEARCH

It has been postulated that the very wide field of view (FOV) visual display systems can override the effects (if they exist) of cockpit motion. The thought being that the peripheral cues available with these very wide FOV systems can provide primary cues which can and do create similar responses to those which are provided with physical motion (cockpit motion).

Certainly this is feasible and conceivably the transfer of training studies conducted by the HRL researchers at ASPT have proven this conjecture. It is, however, extremely unlikely that all training simulators will be equipped with a visual display capability as sophisticated (and expensive) as that found on an experimental research tool. For example, the US Navy currently employs approximately 73 cockpit motion base equipped training devices of which less than 20 percent have visual display capability of any kind and only three have a wide FOV capability (which is barely one-half that of the ASPT device).

There is another factor of interest along this line of thought. The relative timing of cues the subject is subjected to is reported (Gum and Albery, 1976) to be of significant importance. The elapsed time between the pilots control activity and the output of the aerodynamic simulation is well defined and measurable in both the simulated and actual aircraft as reported by Harris (1977). Remember, the output of the aerodynamic simulation constitutes the input to both the visual display system and the cockpit motion system, each of which has its own inherent delays. Ideally, the outputs of the visual and motion hardware would occur simultaneously. In practice, however, this is rarely the case, and the effects on pilot performance of this mismatch in stimuli are not well known. They are, however, currently being studied by Miller and Riley (1977) of NASA Langley.

EXPERIMENTAL DESIGN

The nature of the experiment performed, the variables recorded, the analysis techniques which were utilized upon the recorded data, and experimenter effects all can have a substantial effect on the conclusions drawn by the researchers. Very few of the studies reviewed during this literature search were truly transfer of training studies. Dr. Koonce's work, which was considered by Roscoe and Hopkins to be a transfer study, has been disclaimed as a transfer study by Dr. Gundry for not having a control and performing a different task structure in the aircraft than was performed in the simulator (visual vs nonvisual). The transfer of training studies which were performed on ASPT may be subject to question in that it has been criticized as having delays, in calculating certain variables, of sufficient length as to affect pilot performance (Rust, 1975; Gum and Albery, 1977).

Caro (1977) summarized Hutton, Burke, Englehart, Wilson, Romaglia and Schneider (1976) as follows: "Likewise, motion out of synchronization with visual or other cues could interfere with simulator control if it made trainees ill or presented misinformation to them. For example, it has been reported that the simulator used in the Air Force ASPT study cited above has time lags in the motion system that make performance of some maneuvers difficult."

While on the subject of transfer of training studies, it should be pointed out that there are some tasks which are of sufficiently high risk or are so damaging to the actual aircraft that they are only trained in the simulator. Examples are multiengine aircraft engine failures during takeoff, rollout or landing; low-altitude, high-speed penetration of enemy controlled airspace and the like. For these tasks, it is unlikely that full transfer of training studies will ever be conducted, although some "quasi-transfer of training" attempts have been made (DeBerg, McFarland and Showalter, 1976), at NASA Ames Research Center, using extremely large amplitude excursion simulators, which can duplicate actual aircraft forces for certain maneuvers, to represent the transfer aircraft. It can then be said, that at least for some tasks, the true training assessment, if it must be a transfer of training experiment, will never be accomplished.

With respect to selection of experimental variables, it has been suggested that both system performance measures such as trials to criterion, error scores, etc., and another class of pilot work load performance measures such as control activity should be evaluated when conducting motion research. Most pilots are extremely adaptive and can often maintain system performance

criteria although their piloting technique and hence their control measures may be dramatically and significantly different. The discussion of this entire section, of course, is likely to be dependent upon a great many other variables such as aircraft type, CG location, maneuver and pilot experience level.

In summary, it is not too surprising to find equivocal results in the research conducted to date. There have been different cockpit motion bases (and different performance capabilities), different drive philosophies (and associated gains, frequencies, damping coefficients, etc.), different amounts of visual display capability, different types of experiments, different aircraft types and different experience level subjects used throughout the research. The questions, methods, and variables are not simple nor should the answers be expected to be.

In closing this section of our literature survey, it is apparent that several conditions must be met before any valid comparisons of research results or replications of research efforts can be accomplished. In order to generalize the results of cockpit motion research, the following conditions must be satisfied:

- a. The performance capability of the hardware (motion and visual display) must be published. This includes excursion, velocity, acceleration and frequency response data for each degree of freedom.
- b. An assessment of the fidelity of the flying qualities and performance of the simulation of the aircraft must be made and published. On numerous occasions the motion base has been blamed for poor response when, in fact, the short period (or roll mode constant, etc.) of the actual aircraft was not accurately simulated. This highlights delays caused by improper aircraft simulation.
- c. The type of cockpit motion algorithms and their associated gains, frequencies, damping constants, scaling of the drives, etc., must be published. In order for this to be most useful of time histories, standardized engineering inputs (steps, ramps, etc.) and Bode plots should be displayed for each degree of freedom. This highlights any system delays and delays from the motion algorithms used.
- d. The importance of daily readiness checks should be emphasized. The correct functioning of the equipment cannot be assumed during any experimental runs.

SECTION V

ALGORITHMS AND DRIVE TECHNIQUES

The broad category of algorithm development has been dominated by the work performed by (or for) NASA. Both NASA Ames Research Center, primarily through the work of Schmidt and Conrad, and NASA Langley Research Center, through the work of Parrish, et. al., have published extensively. There has been some developmental work published by the airframe manufacturers such as Northrop, (Mills, 1967; Sinacori, 1973; Sinacori, 1977; Gallagher, 1970) and Ling Tempco Vought (Hayden, 1970). Curiously, very little has been published by the simulator manufacturers or the Armed Services simulator agencies. The description of the motion model used in the Advanced Simulator for Pilot Training (Kron, 1975) and platform simulation (Odierna, 1970) are exceptions.

Prior to the work of Schmidt and Conrad, the algorithms encountered in simulation work were generally found to be a collection of various empirical algorithms based upon either proportional, clipped or, occasionally, washout schemes driving motion bases with usually less than six degrees of freedom. Schmidt and Conrad's work (Schmidt and Conrad, 1970 and 1971) summarized the available literature, determined the cues of importance, synthesized logic for commanding motion, formalized it (Conrad, 1973), and finally, offered the methodology for the coordination of the linear and angular degrees of freedom (Conrad, Douvillier, and Schmidt, 1973). This coordination takes either of two forms. The first, for translational cue simulation, involves using angular displacements or tilting the motion base, at subliminal rates, to provide a sustained cue following a linear displacement used to provide the onset of the sustained translational cue being simulated. The second form is used when the desired cue is a rotational cue. If the onset cue is presented using only the angular displacement capability, a false linear cue is generated due to misalignment of the gravity vector. This coordination scheme provides a translational cue to offset the false gravity contribution. The work of Schmidt and Conrad was verified on large scale cascaded gimbal-type motion drive equipment at the Ames Research Center.

NASA Ames also had some work performed for them, by Singer-Kearfott (Friedland and Ling, 1970; Friedland, Ling, Chong-Kuan and Hutton, 1973), directed towards applying the procedures of optimal control theory to the task of optimizing the motion cues provided within the operational constraints of the motion drive hardware (excursion, velocity and acceleration limits). A series of reports describes this, as yet unproven, effort.

Further publications from NASA Ames include published algorithms for other motion simulators (Beyroty, 1974; Bray, 1972) and coordinate transformation schemes (Douvillier and Coate, 1962).

Throughout the early and mid-1970's a major portion of the developmental work on cockpit motion drive philosophies was conducted at NASA Langley Research Center. Parrish, Dieudonne and Martin adapted the work of Schmidt and Conrad to the so-called synergistic six-post system which was designed at the Franklin Institute by Cappel and made so popular by the various simulation manufacturers. This effort necessitated the development of strut extension algorithms, inverse strut extension algorithms (Dieudonne, Parrish and

Bardusch, 1972), centroid transformations, and washout circuitry (Parrish, Dieudonne and Martin, 1973). Langley personnel improved the dynamic performance of their six post motion base by selectively compensating for hardware delays and filtering update frequency noise from the drive commands (Parrish, Dieudonne, Martin and Copeland, 1973).

Langley research personnel expanded the work of Schmidt and Conrad by introducing new non-linear methods of coordinating translational and rotational motion commands based upon the methods of continuous steepest descent (Dieudonne, Martin and Bowles, 1973) and the use of digital controllers, linear filters and non-linear adaptive filters (Parrish and Dieudonne, 1973; Parrish, Dieudonne, Martin and Bowles, 1973). An additional developmental effort focused on using variable coefficient linear second order filters whose coefficients vary with motion base position enabling improved low-frequency response characteristics (Miller, 1974).

A related, though separate, area of endeavor which has seen a considerable amount of research and developmental activity is the area of simulating turbulence. Prior to approximately 1970, most turbulence simulations utilized random noise generators of approximately Gaussian distribution. The Link Group of Singer proposed a sinusoidal and random buffet simulation in 1967 (Cutts, 1967). Simulation of the non-Gaussian nature of turbulence was deemed important by several researchers who published several papers on the methodology to be used in constructing the newer turbulence simulation (Reeves, 1969; Kurkowski, 1971; Jones and Tomlinson, 1971; Reeves, 1974). NASA continued researching this area as late as 1975 (Jacobson and Joshi, 1975). The simplified technique used in the ASPT simulation of buffet was published in 1977 (Cyrus and Templeton, 1977).

SECTION VI

EFFECTS OF MOTION

"No point of view has absolute, permanent validity. Each has importance only for some given end."

Ernst Mach
(The Analysis of Sensations, 1897)

This section has been divided into two main topics: psychophysiology and control performance. Grouped under "psychophysiology" are publications concerning perception of motion or the effects of motion on the human body. Under "control performance" are included publications concerned with the effects of motion on the human operator's ability to perform a psychomotor task.

PSYCHOPHYSIOLOGY

a. Sensation and Perception. An important research area is in the investigation of the perception of motion. There is a need for a psychophysics of motion to provide data on motion thresholds, including difference thresholds, and motion scaling. Although, it provides useful information, it is not sufficient to specify that a particular motion has a threshold value. The objective is to discover certain relations among frequency, amplitude, perception latency and directions of motion. A determination of how the various combinations affect the motion sensing capabilities of the human will, then, permit generalizations to be made. Huddleston's (1966) and Clark's (1967) papers summarize much of the work done on motion thresholds. Problems of measuring thresholds and recommendations for threshold measurement methods relevant to flight simulation are discussed in "Man and Motion Cues" (Gundry, 1976).

One of the largest obstacles to settling the question of motion is the definition of the stimulus. Investigators in this area have not fully agreed on the absolute thresholds to motion stimuli, as illustrated by Wendt's (1967) comments on Huddleston's (1966) paper concerning motion requirements for flight simulation. As stated by S. S. Stevens in the Handbook of Experimental Psychology (1951), "...the complete definition of the stimulus to a given response involves the specification of all the transformations of the environment, both internal and external, that leave the response invariant. This specification of the conditions of invariance would entail, of course, a complete understanding of the factors that produce and that alter responses."

Dr. Clark, in his paper on Thresholds for the Perception of Angular Acceleration in Man (1967), noted two serious limitations of the majority of the 25 studies that he reviewed. First, the small number of subjects in any one study and, second, the stimulus was not measured directly. In addition, the various experimenters did not have common definitions of "threshold" and did not describe clearly how the thresholds were determined. Almost all the studies reported data on yawing acceleration while only two reported thresholds for roll. The thresholds reported varied between $0.035/\text{sec}^2$ and $8.20/\text{sec}^2$ with a median around $1.00/\text{sec}^2$.

Wendt (1966) reported angular acceleration thresholds from laboratory data that ranged from $0.2^\circ/\text{sec}^2$ to $2^\circ/\text{sec}^2$, assuming long latency periods. When response latency was the criterion, approximately two seconds were required to detect $3^\circ/\text{sec}^2$; three seconds to detect $2^\circ/\text{sec}^2$; and almost seven seconds to detect $1^\circ/\text{sec}^2$. In terms of the short durations applicable to many aircraft maneuvers and their simulation, there is little sensitivity to changes of angular motion in the absence of other cues. Some data suggest that, if the maximum response latency is held to about 1.5 seconds, and if latency is taken as the chief criterion of threshold, then the average subject cannot tell $4^\circ/\text{sec}^2$ from 10 or $15^\circ/\text{sec}^2$ accelerations.

As the disparity between laboratory data and operational performance is very wide, the laboratory measurement of thresholds may be of academic interest only. At best, laboratory findings indicate levels that the pilot will not be able to perceive in the simulator or aircraft. For the practical purposes of simulator operation, Wendt (1966) recommends raising the laboratory thresholds by a factor of two to ten or more.

In addition to the inconsistencies in measurement techniques and definitions of thresholds already alluded to, other reasons for the unreliability of applying laboratory threshold data to the design of simulators are the differences in the distance of the subject from the axis of rotation in the laboratory apparatus and in the simulator. Most important, however, is the difference between the subject's task in the laboratory and in the simulator. In the laboratory, the subject's task is to detect motion, whereas, in the simulator, his task is to "fly." The outputs of the kinesthetic sense do not under normal conditions reach awareness until attention is directed at them. The problem is that any conventional technique of measuring thresholds involves concentration on motion effects only. If this is done in a flight simulator, the subject's primary task, that of "flying" the simulator, is altered. The act of measurement itself invalidates the simulation (Gundry, 1976).

As stated by Gundry (1976), "In order to determine the threshold levels to motion which are in principle present during flight simulation, a procedure must be used which does not require the subject to attend to motion cues any more than he would during normal operation of the simulator."

Dr. Gundry recommends investigation of the operator's use of motion stimuli while tracking as a solution to this problem. He states that, "...once a minimum value of a motion cue has been established which affects operator performance in a tracking task, an effective threshold to motion has been established. The operator may or may not be able to detect the motion cue at the level that influences his behaviour -- this is immaterial as long as the motion cue at that level produces a change in behaviour."

An area which appears promising for motion system design and evaluation is that of modeling of the human sensory mechanism. Usually, the fidelity of a simulation is assessed by comparing simulator performance with aircraft performance. The use of sensory system models permits comparison between the pilot's perception of motion in the simulator and the aircraft. Experimental

studies have been conducted in an attempt to establish the relation between actual motion and its subjective perception. For example, Bergeron (1970) conducted tests with reduced scaling on the motion input to investigate the minimum requirements of motion cues for one- and two-axis closed-loop tracking tasks.

For information on modeling of the human motion-sensing mechanisms, the following publications are recommended: Borah, Young and Curry (1970, Gum (1973), Young, Oman, Curry and Dichgans (1973), and Junker and Levison (1978).

b. Spatial orientation, including disorientation, illusions, and vertigo are entered in this section.

"The expression 'sense-illusion' proves that we are not yet fully conscious, or at least have not yet deemed it necessary to incorporate the fact into our ordinary language, that the senses represent things neither wrongly nor correctly. All that can be truly said of the sense-organs is, that, under different circumstances they produce different sensations and perceptions. As these 'circumstances', now, are extremely various in character, being partly external (inherent in the objects), partly internal (inherent in the sensory organs), and partly interior (having their activity in the central organs), it can sometimes appear, when we only notice the external circumstances, as if the organ acted differently under the same conditions. And it is customary to call the unusual effects, deceptions or illusions," according to Ernst Mach, in The Analysis of Sensations, 1897.

Pilot instrument training is a known technique for preventing or recovering from spatial disorientation. In addition to instrument training, spatial orientation training should be employed to familiarize the pilot with the causes of the illusions experienced during disorientation, and to train him on countermeasures to prevent or overcome the effects of the misleading cues which cause the phenomenon (Bonner, 1963). A spatial disorientation device, designed and constructed at the request of the Air Force is described by Lewis (1965). This device combined the principles of the Barany chair and a low-performance centrifuge. Bonner (1963) described other special training apparatus such as the trampoline, Ren wheel, looping device, 4-pole swing, and the Ruggles Orientator.

c. Visual-Vestibular Interaction. The sensations which conflict most frequently with visual perceptions are those originating in the vestibular system of the inner ear. Sensory interactions between the visual and vestibular apparatus are very important to consider in simulator applications which couple a visual display to a motion system.

A few documents concerning the visual perception of motion are also included in this section. The reason for this is that the visual and proprioceptive perception of motion are so closely interwoven and interdependent that it is difficult to separate the two. On the other hand, a deeper search into the visual perception of motion would result in compiling a large number of references in this area -- a task somewhat divorced from the main theme of this report.

Effective training design requires that the significance of cue interactions be established. Researchers can be misled by extrapolating the results of single-variable experiments to applications that involve many variables. Care must be taken to incorporate into the training device not only the stimuli required for training in specific tasks, but the essential combinations of stimuli as well. In addition, it is important that the perceived pattern of cue combinations actually represent those of the operational environment.

d. Motion Sickness (Simulator Sickness). A factor which favors the inclusion of motion as part of a total simulation system is the possibility that motion may act as an inhibitor of simulator sickness. It has been hypothesized that the cause is related to the increase in neural activity from eye movements following a changing visual scene which is contrasted with the static physiological cues from the proprioceptive system. However, it is generally very difficult to isolate the causes of simulator sickness, and it is even possible to develop sickness in a static situation such as in a room tilted from the inertial vertical.

A distinction is sometimes made between "simulator sickness" and motion sickness which develops in animals and humans when they are physically moved under certain conditions. In simulator sickness, the individual may be subjected to real motion but in many cases he is not. Howard and Templeton (1966) do not make this distinction and state that vestibular stimulation is not a necessary condition of motion sickness (p. 137).

Susceptibility to motion sickness, or "simulator sickness," may be related to the individual's cognitive style of perceiving his environment. The field-dependence dimension is the most widely studied of the cognitive styles. This trait may be measured with a standard Rod and Frame Test (RFT), the body-adjustment test (BAT) or the Embedded-Figure Test (EFT) which measures field dependence in a purely visual, paper-and-pencil situation (Anastasi, 1961).

Field dependence is probably the first trait that should be measured before proceeding with any simulator studies concerning motion. This trait may be useful not only for screening of individuals susceptible to motion sickness but also as a predictor of training success (Kennedy, 1975). It may also be found that different kinds of training may be needed for field dependent and field independent types of students.

e. Stress. There is no exact definition of stress. The word has been used as a vague synonym for "unusual or unpleasant working conditions." Many attempts have been made to define stress more precisely and to develop theories of psychological stress so that all of the varied findings can be covered by one explanation, but no theory has yet received general acceptance. Perhaps the most promising approach is the work on "arousal," "activation," or "energy mobilization" where the findings of both psychology and physiology are being brought together. There is some evidence that there is an optimal level of "stress" as it affects performance. If the level of "stress" by motion or other form of stimulation increases or decreases from the optimal level, then the level of performance declines (Gillies, 1965).

f. Acceleration. Another major research area is in the investigation of the physiological effects of acceleration upon the human body. The publications selected for this section deal primarily with the sensory aspects and human tolerance levels to acceleration. The effects of acceleration on performance are covered in the next section, Control Performance.

The effect of vibration on human physiology, fatigue and performance has been intensively studied by Goldman and Von Gierke (1960) who provide extensive surveys of this field.

CONTROL PERFORMANCE

Classification of motion may provide a method for clarifying the "motion question" which is, in fact, a multi-faceted question. The general term "motion" may be too broad to apply to task-related motion requirements. Accordingly, a classification scheme which distinguishes among the different types of motions may be useful in separating out the various issues.

According to an analysis by Graham (1968) physical motion is required for:

Tasks during which motion aids the pilot (e.g., carrier and other than normal approach and landing tasks, V/STOL low-speed operations, evaluation of training or primary controls and displays, pursuit tracking).

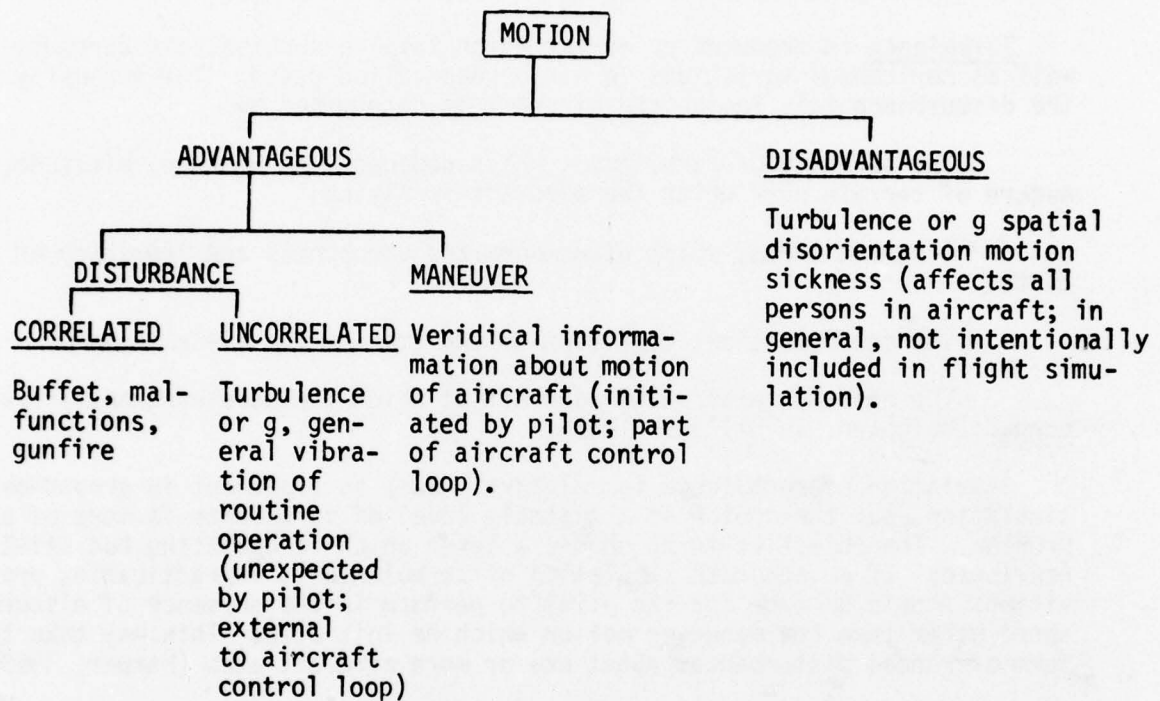
Tasks during which motion hinders the pilot (e.g., flight in turbulence, emergency procedures, tasks involving high 'G' forces).

Matheny, Lowes, Baker and Bynum (1971) dichotomized motion into correlated and uncorrelated. In a more recent report Matheny, Lowes and Bynum (1974) defined them as follows: "Correlated motion is defined as that motion which is coincident with changes in the aircraft state. In the simulator, it is intended to represent aircraft system movement about its axes in three-dimensional space."

"In some moving base trainers low amplitude random motion loosely described as "break-loose" vibration has been introduced. Such motion is independent of, or uncorrelated with, control movement or visual display. Generally, it has been added either to create an illusion of realism, to mask erroneous cues produced by stiction of the hydraulic actuators of the simulator platform or to prevent such stiction."

Matheny et. al. go on to say, "This uncorrelated random motion may be perceived differently and have varying effect upon performance depending upon its spectral composition. It may be perceived as non-relevant, background motion which enhances the realism of the trainer. On the other hand, it may provide above threshold stimuli which conflict with the visual information being perceived by the pilot. At certain frequencies it may degrade visual acuity or interfere with the production of accurate control input movements on the part of the pilot."

More recently, Gundry made a distinction between motion as a signal or cue, and motion as a task element or noise. In his paper (Gundry, 1976) on roll motion thresholds, he classified motion as advantageous or disadvantageous with a further subdivision of advantageous motion into disturbance and maneuver motions. This scheme is shown diagrammatically below:



a. Vibration, buffet and turbulence are related but involve different motion characteristics, therefore, the following definitions may be found useful:

Vibration has been defined by Crede (Gillies, 1965) as a series of reversals of velocity. A more restricted definition, relating to human physiology defines it as a sustained, structure-borne disturbance, applying a translatory movement to the body and perceived by the senses other than hearing (Guignard, in Gillies, 1965). Crede's definition is a useful concept for the physiologist even though it does not include all conceivable modes of vibration. For example, buffet and turbulence can be regarded as special cases of vibration which do not necessarily involve reversal of velocity. Velocity implies displacement in finite time; and the reversal or change of velocity involves acceleration and higher derivatives of displacement with respect to time.

The displacement and its time derivatives may be in translation, which is the type of motion usually considered, or in rotation (torsional vibration). The vibration may be free, as in the oscillation of a pendulum, or forced, in which case the disturbance is maintained by an applied force. The papers in this section are concerned primarily with forced vibration. The fluctuations of the exciting force may be periodic, giving simple or complex harmonic

motion, or non-periodic, resulting in transient or random vibration (Gillies, 1965).

Buffeting involves rapid, erratic variations in lift resulting from irregularly moving shock waves on the wing surfaces of an aircraft. This generally precedes the onset of sudden changes in trim which may cause loss of aircraft control (Gillies, 1965).

Turbulence is produced by eddies which involve vertical air currents as well as horizontal variations in wind speed called gusts. The intensity of the disturbance felt inside the aircraft is determined by:

- The severity of turbulence, which depends upon weather, altitude, and nature of terrain over which the aircraft is flying;
- Aircraft speed, which determines the abruptness and frequency of the gusts;
- The configuration, construction and trim of the aircraft; and
- The position within the aircraft at which the accelerations are recorded (Guignard, in Gillies, 1965).

Simulation of turbulence is relatively easy to implement in ground-based simulation, but the choice of a suitable level of turbulence is more of a problem. The objective is to choose a level which is upsetting but still realistic. If an accurate simulation of turbulence is impracticable, provisions should be made for the pilot to perform in the presence of disturbances other than the maneuver motion which he initiates. This may take the form of random disturbances about one or more aircraft axes (Harper, 1963).

b. Low-altitude, high-speed flight presents the pilot with the demanding and dangerous task of flying close to the ground while being exposed to relatively high levels of turbulence. Attack missions frequently involve terrain clearance requirements of altitudes between 200 and 500 feet. The usual effect of high-speed flight at these altitudes is a random buffeting of the aircraft. The aircraft may vibrate at frequencies dependent on aerodynamic design and it may be accelerated violently in many directions. These movements tend to disrupt the pilot and interfere with his performance. Random buffet cannot be precisely described in terms of specific frequencies, amplitudes, and periodicities, because the phase relationships are unknown. For this reason, the power density spectrum of the motion is used to describe it (Buckout, Sherman, Goldsmith and Vitale, 1963).

The Buckout et. al. (1963) study concluded that:

Simulated motion during the learning of tracking skills contributes to more effective performance in criterion test situations in which motion cues play an important role (i.e., flying a high-speed, low-altitude mission through clear-air turbulence).

Performance on a procedural task (reaction time measures) during criterion testing, did not differ significantly as a function of the type of training received (motion vs. no motion).

One of the conclusions of the study by A'Harrah and Schulze (1963) was that, "The moving-base flight simulator ("G" seat) utilized in this program provides a realistic and efficient means by which pilots can evaluate the short-period longitudinal stability, control, and gust response characteristics for LAHS flight."

c. A pilot-induced oscillation (PIO) is an inadvertent sustained oscillation of the pilot-vehicle system. When a PIO develops, the aircraft motions change from a random-like to a nearly sinusoidal form. Ashkenas et. al. (1964) analyzed several causes of PIO. One cause, discussed in their paper, results from insufficient training.

PIO is not restricted to aircraft. Simulators sometimes exhibit PIO tendencies even though they may not have been designed to do this. For instance, pilot induced roll-axis oscillations appeared during landing tasks when a computer-generated image (CGI) display was added to the TA-4J Aircraft Operational Flight Trainer, Device 2F90. A similar problem was encountered years earlier on a carrier landing simulator, Device 2H87, which used a model board/television system. In these cases, the oscillation was apparent in the visual system. Any motion of the motion system appeared to be negligible.

A simulator designed to adhere closely to the equations of motion of a particular aircraft should, theoretically, be able to develop PIO under the same conditions that would cause it to develop in the aircraft. Pilots could then be trained in the simulator to counteract the PIO. Whether fixed-base simulators are adequate for this type of training is questionable. Proprioceptive cues coupled with the disruptive forces of cockpit motion may be necessary for adequate representation of the condition which the pilot must learn to counteract. The presence or absence of motion should influence the control behavior of the pilot. Depending on the frequency and magnitude of the forces being simulated, the motion may aid or hinder the pilot's control movements.

The limited literature on the effects of maneuver motion alone indicate that this type of motion is only important in the control of unstable systems (Meiry, 1965; Sadoff et. al., 1961; Perry and Naish, 1964). Motion cues provide the pilot with anticipatory information in the form of phase lead which is useful in overcoming instability such as that produced by pilot-induced oscillations.

The duplication of deliberate, specific types of PIO on a simulator, however, is very difficult to accomplish in practice. As stated by Belsley (in Harper, 1964):

"Some flight control problems, such as pilot-induced oscillation, have yet to be duplicated on motion flight simulators, for as the overall pilot airframes system approaches the condition of neutral damping, the subtleties of all the motion cues plus any control system nonlinearities tend to dominate the problem."

By design, most production aircraft are stable and do not exhibit PIO tendencies. For this reason, most pilots will not deal with this eventuality. Training in this area, therefore, is not considered a critical requirement.

d. Handling Qualities. McDonnell (1968) defines "handling qualities" as follows:

"Handling qualities may be defined as those characteristics which determine the control nature and behavior of pilot/vehicle systems. In this context a handling quality is, therefore, any property of the pilot/vehicle system which relates to open- or closed-loop command or regulation. Handling qualities thus include any properties or attributes of the vehicle and the pilot as they interact, either actively or passively, in the pilot/vehicle system."

This definition is expanded further on pages 14-15 of his report, "Pilot Rating Techniques for the Estimation and Evaluation of Handling Qualities."

Cooper and Harper (1969) in their discussion of handling qualities proposed to clarify and standardize the terminology used in this field. Their definition of the term "handling qualities" emphasized that it includes more than just stability and control characteristics. McDonnell, in his broad definition of the term, tends to agree with this concept. As stated by Cooper and Harper:

"Other factors that influence the handling qualities are the cockpit interface (e.g., displays, controls), the aircraft environment (e.g., weather conditions, visibility, turbulence) and stress, the effects of which cannot readily be segregated. Thus in most tests, handling qualities are really being evaluated in the aggregate."

In Appendix A of the Cooper and Harper report, "Handling Qualities" is defined as "those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role." The generally accepted meaning of "flying qualities" is similar to this definition and is considered to be synonymous with "handling qualities."

e. Time delays enter simulations of flight from a variety of sources. Pilot control inputs must be sampled, the aircraft's responses to them must be calculated and displayed, and then this sequence must be repeated again and again for the duration of the simulation. The calculation time of the aerodynamic model will determine the rate at which this can be done, and time delays associated with various display systems will add to that processing interval. Computer-generated visual displays, for instance, presently take about 100 milliseconds to calculate their images, and motion platforms usually take considerably longer to overcome their own inertias. A problem common to both platform motion systems and the G-seat is that of excessive time lag. For example, the software programs for the ASPT run at real time frequencies of $7\frac{1}{2}$ to 15 iterations/sec, or 133 to 66 milliseconds processing time. When hardware and software lags are added, the total lag is about 275-475 milliseconds from the time of pilot input (Albery, Gum, and Hunter, 1976). Not all motion systems involve lags of this magnitude; however, Parrish, Dieudonne, Martin, and Copeland (1973) have improved the response of the motion cueing system of the Langley Research Center Visual-Motion Simulator until its total system delay is on the order of 90 milliseconds.

Time delays create problems for manual control in that the phase margin that the controller produces is reduced by the delay, making the man/machine system less stable and hence the accuracy of control suffers. A host of experiments have demonstrated this deterioration of tracking, and good reviews of these laboratory studies have been presented by Muckler and Obermayer (1964), Poulton (1974), and Ricard and Puig (1977).

Often the variables sent to the various display systems of flight simulators are adjusted to try to cope with processing times and system lags, and these changes often introduce problems of their own -- usually an increased responsiveness that is annoying if the display system itself is responsive. Cooper, Harris, and Sharkey (1975) demonstrated that most of the differences between control of a delayed system and a normal one are low-frequency -- a finding that opened the possibility of attenuating the noise of the adjusted signals without affecting the "signal" portion. Ricard, Norman, and Collyer (1976), and Ricard, Cyrus, Cox, Templeton, and Thompson (1978) have presented some results of compensating for delays in this manner. An efficient way to produce the compensation used in those studies is described by Cyrus (1977).

Another problem that time delays cause for simulator-based flight training is that the outputs of different display systems lag the output of the aerodynamic model by different amounts. This reduced temporal congruence of cues for aircraft motion have been a source of worry -- especially since Miller and Riley (1977) have shown that too great a temporal disparity can cause nausea. Few data exist on this aspect of device design, but some may be available soon (Junker, 1978). When the cues do correlate, the presence of the cues produced by a device's motion base do aid control in the presence of a delay, extending the visual system delay that can be tolerated for a given simulation.

f. Acceleration. The centrifuge is an alternative device to the aircraft simulator. It provides a means for simulating sustained acceleration cues for much longer durations than is possible on conventional motion-base simulators. The centrifuge, however, produces unwanted Coriolis effects which can disorient and produce motion sickness. These anomalous effects are disconcerting to the subject and, generally, affect his performance, thereby contaminating any experimental results. Brown (1960) discusses the limitations of centrifuge simulation. He states that the disadvantages must be taken into account, but, in general they appear to be outweighed by the advantages of centrifuge research.

Much of the literature on the effects of acceleration on pilot performance and human tolerance to acceleration, has been generated at the Aviation Medical Acceleration Laboratory Centrifuge, Naval Air Development Center, Warminster, Pennsylvania. Another Navy organization that studied acceleration effects was the Naval Aviation Medical Research Laboratory at Pensacola, Florida.

Probably, the most frequently studied effect of centrifugation on human tolerance and performance has been the perception of motion and orientation in space as sensed by the vestibular organs. Vision, however, is the sense modality most dramatically affected by acceleration. For an excellent review of the effects of acceleration, on the senses, motor behavior, complex tasks,

cognitive processes, and psychological effects, the articles by Brown and Lechner (1956) and Brown (1960) are highly recommended.

g. Tracking. There is a voluminous amount of literature on tracking; however, we have included only those studies related to motion simulation. A tracking task using an oscilloscope presentation is often used for studying the effects of motion. In fact, Gundry (1976) recommends the use of tracking as a procedure for determining practical motion thresholds during simulator operation. He stated that, once a minimum value of a motion cue which affects operator tracking performance has been determined, an effective threshold to motion has been established.

For those interested in other aspects of tracking, it is recommended that they refer to Mehr's Bibliography of Tracking Controls (1967) which has 371 entries. Another excellent, and more recent source is Poulton's (1974) book, Tracking Skill and Manual Control, which contains 370 references.

To summarize, there is experimental evidence that:

(1) Motion can be reduced without significant change in the simulator operator's performance. References: Bergeron (1970); Matheny, Lowes and Bynum (1974). Note: As Gundry (1976) pointed out, these experiments used disturbance and maneuver motion with the main task as tracking a disturbance input. Dr. Gundry stated that what should be used to determine minimum levels of motion is the degree of maneuver motion required. He recommended that similar experimentation be conducted using a command input and maneuver motion.

(2) Motion simulation results in better performance than fixed-base simulation. References: Beck (1974); Bergeron and Adams (1964); Buckhout, Sherman, Goldsmith and Vitale (1963); Cooper (1963); DeBerg (1976); Douvillier, Turner, McLean, and Heinle (1960); Flexman (1966); Gerathewohl (1969); Guerico and Wall (1972); Huddleston (1966); Matheny, Dougherty and Willis (1963); Rolfe, Poulter and Smith (1968)*; Ruocco, Vitali, and Benfari (1965); Sadoff and Harper (1962). See Figures 12, 13, 14, 15.

(3) Motion did not produce better performance than no motion. References: Gray and Fuller (1977); Waters, Grunzke, Irish and Fuller (1976); Woodruff (1976); Irish, Grunzke, Gray and Waters (1977); Martin and Waag (1978); Irish and Buckland (1978); and Cyrus (1978).

* (In Rolfe, Ed., IAM Report 442.)

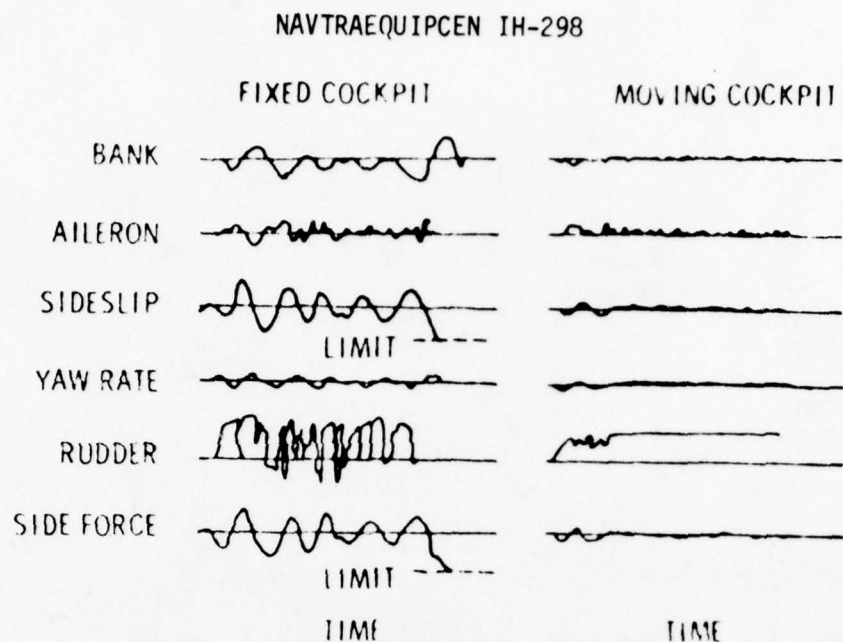


Figure 12. Effect of Cockpit Motion on Pilot Controllability Following Abrupt Engine Failure
(from Cooper, 1963)

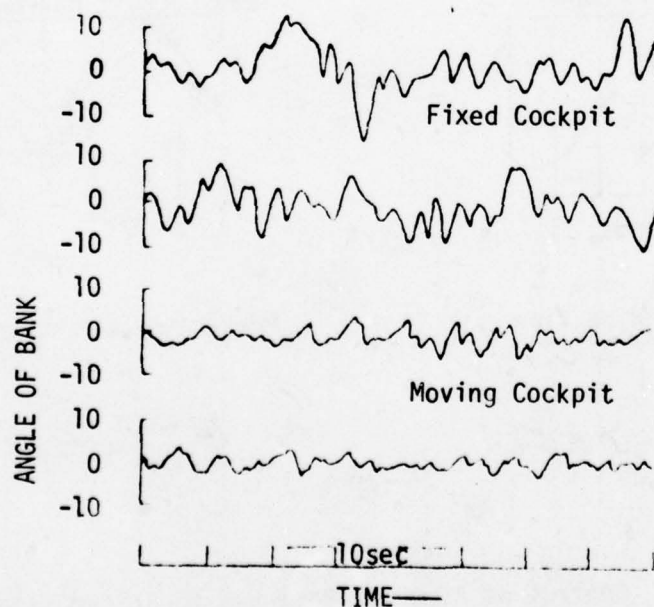


Figure 13. Effect of Cockpit Movement on Control in Turbulence
(from Perry & Naish, 1964)

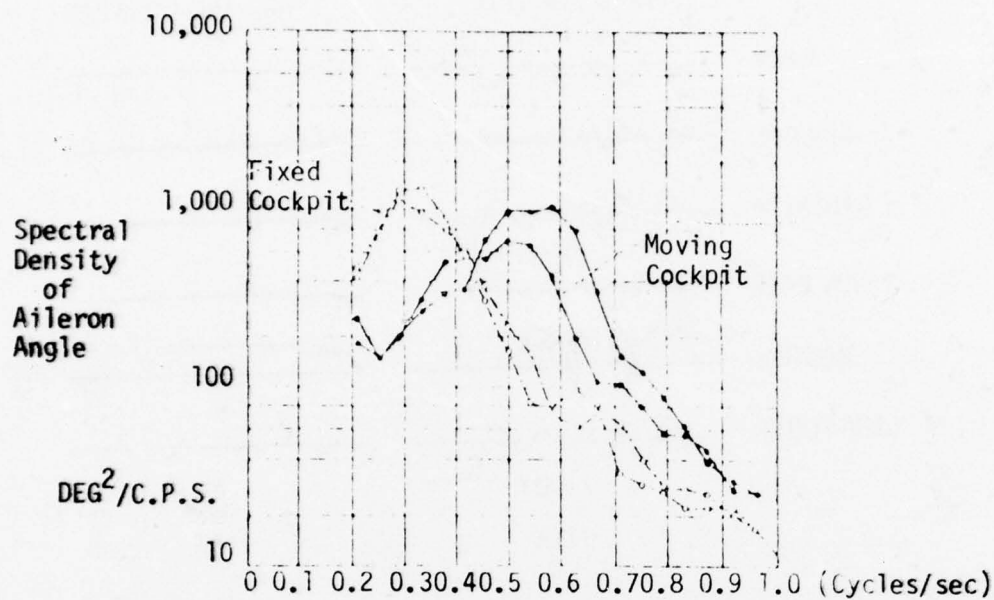


Figure 14. Analysis of Control Angles in Fixed and Moving Simulation

(from Perry & Naish, 1964)

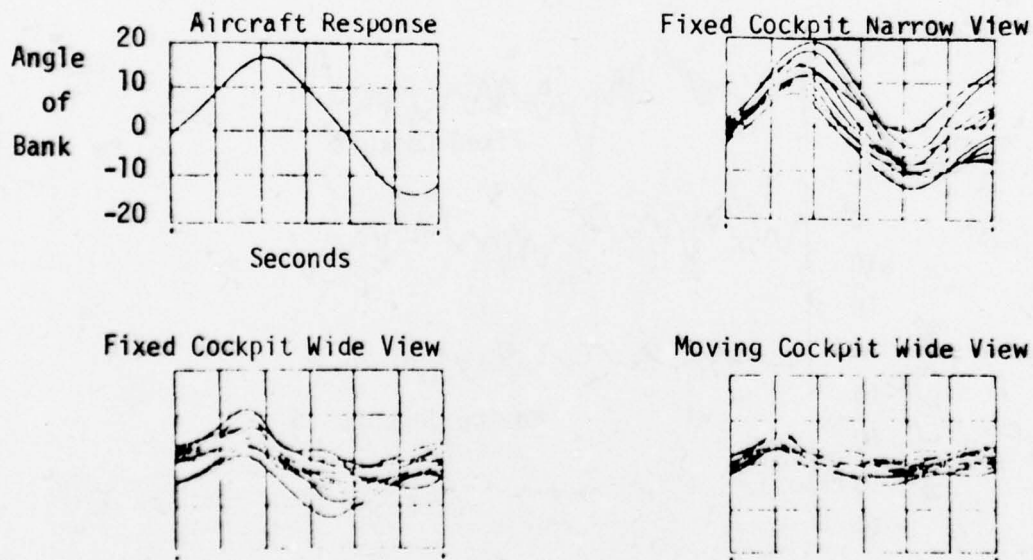


Figure 15. Control of Aircraft Response to a Step Side Gust with Different Simulation Cues

(from Perry & Naish, 1964)

SECTION VII

EVALUATION

"In discussions on method and scope, a man is nearly sure to be right when affirming the usefulness of his own procedure, and wrong when denying that of others."

Alfred Marshall
(Principles of Economics,
Macmillan, 1890)

In attempting to provide a brief review of the current status of motion systems evaluation, it must be borne in mind that the field of training evaluation is as yet not an exact science. The inability to resolve the basic issues of the role of motion in simulation by the application of an effective methodology can be explained, at least partially, by the slow developments in this field.

Although some work in training evaluation can be traced back to the early 1900's, it was not an area of widespread interest because the value of training was taken for granted, and it was assumed that there was little need to evaluate it. The emphasis at that time was upon traditional scholarship as opposed to experimental methods.

The recent emphasis on the substitution of simulation for in-flight training resulted from the energy shortage and concern over the value of training per dollar spent. This sudden interest has placed an unexpected demand upon the field of training evaluation which had not advanced as rapidly as other, more popular fields. The traditional methods of evaluation were based almost exclusively on instructor ratings and questionnaires as measures of training. These methods are subject to the criticism of being too subjective.

More recently, experimental and quasi-experimental techniques have been used; however, lack of standardization of terminology and omission of precise definitions of the motion drive algorithms and apparatus used, has produced results which are difficult to interpret and replicate. To condense the results of these studies into a single generalization would be very risky. This topic has been discussed more thoroughly in Section IV, Requirements.

Despite the many obstacles found in the way of effective evaluation techniques, the major obstacle is the criterion problem. As stated by Gagne (1954), "When one inquires about the effectiveness of a device for training, one is really asking about transfer of learning to some criteria." This major problem involves the translation of training objectives into criteria. Although the type of experimental design is also a very important consideration, the ultimate strength of evaluation is in the criteria selected (Campbell and Stanley, 1963).

Despite this somewhat pessimistic introduction, the question of the value of motion in simulation should eventually be answered through experimental evidence. For this reason, this section is a compilation of studies that attempt to assess the value of motion in research and training simulators.

TRAINING EFFECTIVENESS

As noted by several authors (Blaiwes and Regan, 1970; Roscoe, 1974; Williges, Roscoe, and Williges, 1973), three criteria must be considered in properly evaluating training effectiveness: (1) efficiency of original training, (2) transfer of training, and (3) retention of training. Unfortunately, the third criteria -- retention -- has been the one most neglected. As stated by Williges et. al. (1973):

"Interestingly, the most common measure of training effectiveness, retention of material learned, has been generally ignored in the evaluation of simulators. Most studies fail to measure the permanence of simulator learning, despite the obvious importance of retaining flying skills."

These authors go on to explain the reasons for this deficiency:

"Measurement of retention is hindered by such problems as variations in the original training of subjects, difficulty of controlling the amount of flying experience each individual pilot receives during the retention period, and unavailability of subjects after a sufficiently long retention period. The lack of simulator studies using a retention measure reflects the general insufficiency of information relating to retention of pilot skills or, for that matter, retention of any complex motor skill."

Considerable progress has been made during the past few years in both developing assessment methods and applying these methods in the evaluation of training devices. This subsection, of Section VII on Evaluation, contains those studies which involve evaluation of the training effectiveness of motion in simulation.

HUMAN PERFORMANCE

The effects of simulator motion on a pilot's ability to perform a flying task is the major concern of the studies reviewed in this subsection. Since it has been observed that a human operator is an extremely adaptive component of the simulation systems evaluated, current evaluation approaches tend to concentrate on human performance as contrasted with overall systems performance.

FIDELITY

"Happiness is a perpetual possession of being well deceived."

Jonathan Swift
(Tale of the Tub)

"Go, go, go, said the bird: human kind cannot bear very much reality."

T. S. Eliot
(Burnt Norton)

If liberties may be taken with these quotations, and we interpret them to mean that the simulator designer has found what the artist has always known about the place of illusions in perception, then so much the better for the art and science of simulation.

Realism per se in the accepted meaning of the term, does not provide a satisfactory basis for evaluating simulator design; transfer and retention of training are the important dimensions. One role that realism plays, however, is that of increasing simulator acceptance and trainee motivation. A trainee may practice more, and practice harder, if he thinks the simulator looks and "flies like the plane" whether it actually does so or not. One of the greatest obstacles to psychological fidelity in aircraft simulation is the inability to simulate all aspects of the aircraft's motion and handling qualities in a way which is acceptable to the student pilot.

SUBJECTIVE APPRAISAL

"When you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."

Lord Kelvin

OBJECTIVE MEASUREMENTS

"When you can measure it, when you can express it in numbers, your knowledge is still of a meager and unsatisfactory kind."

Jacob Viner

Subjective appraisal is usually criticized on the basis of its lack of consistency whereas the requirement for objective measurement is emphasized. Although not always as consistent, pilot opinion is usually more sensitive to handling qualities than objective measures provided by automated equipment. In addition, pilots can be trained to give consistent ratings which correlate highly with objective measures. Subjective and objective measures both can be valuable analytic tools and should be used to supplement each other.

Pilot opinion of handling qualities has been used for design guidance since the early 1930's (Frost, 1972). In 1957, George E. Cooper of the NASA Ames Research Center encouraged the standardization of rating systems and constructed the Cooper Rating Scale. Since this scale was constructed, modifications have been made as a result of objections that were raised to the limitations of the earlier scale. One of the primary aims was to increase the inter-rater reliability of the instrument. Two new revisions, the Cornell Aeronautical Scale (Harper and Cooper, 1966) and the Systems Technology Scale (McDonnell, 1968) resulted. These revisions have increased inter-rater reliability by clarifying the relation between task and mission, and spreading the rating categories more uniformly on a scale of acceptability.

The experimental measurement of performance cannot yet replace pilot evaluation. Measurement of system performance is not sufficient because good performance is not always related to good handling quality. The pilot, being an adaptive controller, is capable of attaining the same performance for a wide range of vehicle characteristics. Significant differences in his task

performance may not be measured when very real differences in mission suitability do exist. However, the control technique (pilot output) required to bring about identical system outputs can vary significantly (Harper, 1964).

COMPARATIVE STUDIES

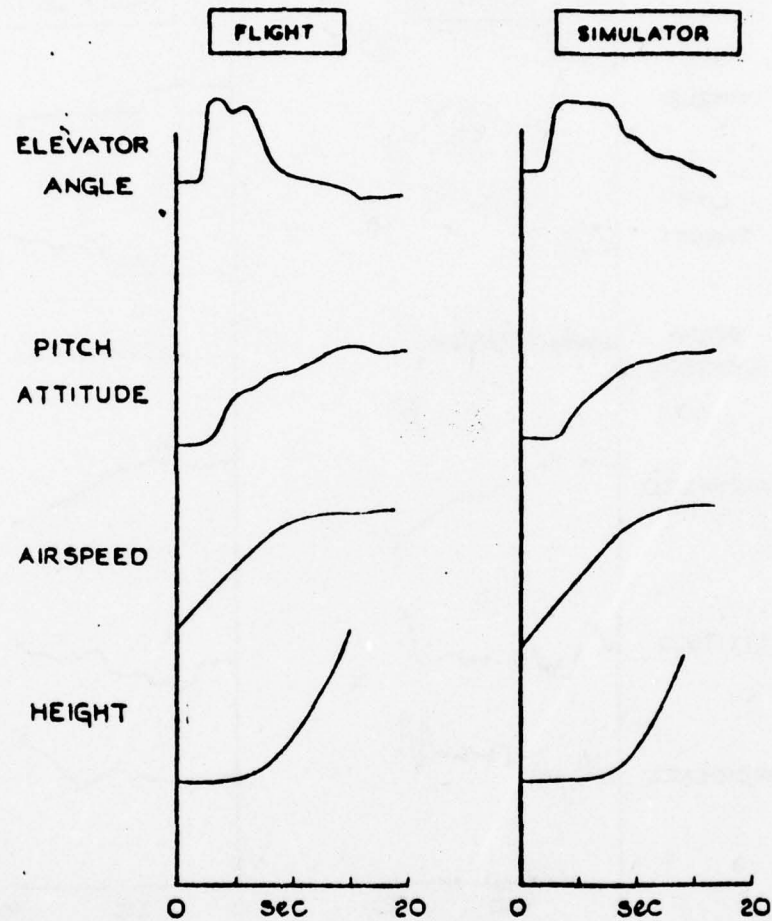
This section contains abstracts of evaluative studies that identify differences between ground-based and in-flight simulation, between performance in ground-based simulators and performance in the aircraft, and variations in performance as a function of motion or static simulation.

A series of such studies has recently been completed by the Air Force Human Resources Laboratory at Williams Air Force Base, Arizona on the Advanced Simulator for Pilot Training (ASPT). Table 5 in Section IV of this report contains comments on these studies (Waters, Grunzke, Irish and Fuller, 1976; Woodruff, 1976; Gray and Fuller, 1977; Irish, Grunzke, Gray and Waters, 1977; Martin and Waag, 1978; Irish and Buckland, 1978; and Cyrus, 1978). Table 3 in Section III includes comparative studies on G-seats.

During the 1960's, a number of comparative studies were made at the Royal Aircraft Establishment, Bedford, England for several types of aircraft and flying tasks (Perry and Naish, 1964; Perry, D. H., 1966). Some time history curves taken from Perry's (1966) report are reproduced in Figures 16 through 19. His explanations of each example follow:

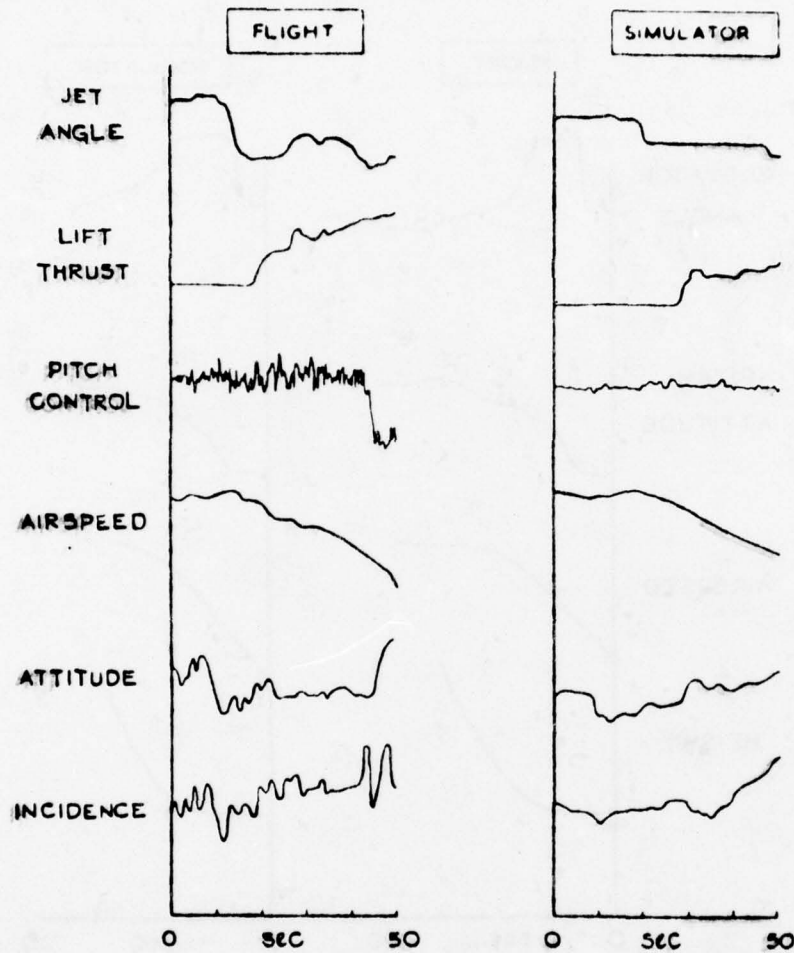
"In the first two figures (16 and 17) time histories of complete manoeuvres made by the same pilots in flight and in the simulator are compared. Figure 16 shows the take-off manoeuvre in a Comet jet transport aircraft, and Figure 17 the transition from wing-borne to jet-borne flight in the S.C.1 vertical take-off aircraft. To establish whether there were significant differences between the behaviour in flight and the simulator it was, of course, necessary to compare many such records, so that the random variation between one manoeuvre and another could be eliminated, but those shown are fairly typical. In the case of the transition manoeuvre (Figure 17) there is an obvious difference in the pilot's pitch control inputs at high frequency, but this is believed to stem from an irregular motion of the aircraft, due to lift engine interference, a feature which was not represented on the simulator. Apart from this particular feature, the general character of the manoeuvres in flight and in the simulator is seen to be very similar. This correspondence, coupled with favourable subjective assessments by the pilots, was considered to give an adequate validation of the simulation in these two cases.

Figure 18 shows a more detailed examination of one particular feature during another flight/simulator comparison. It concerns aileron control usage during flight through turbulence on the Avro 707A, a small delta winged research aircraft. Again the same pilot was flying in each case. The time histories of aileron usage show good correspondence, both in the general characteristics of the way that the controls were used, i.e. in frequency content, and in the variation in amplitude with the level of turbulence. But pilots' subjective assessments in this case were that the simulated task was more difficult than that in real flight, probably because cockpit motion was not used. Good aircraft attitude information was available from the horizon display.



(from Perry, 1966)

Figure 16. Comparison of Actual and Simulated Takeoffs in a Jet Transport Aircraft



(from Perry, 1966)

Figure 17. Comparison of Actual and Simulated Transitions in a Jet-Lift V.T.O.L. Aircraft

Under more exacting conditions the lack of cockpit motion may lead to more obvious difficulties in controlling the simulator. Particular cases where this has been observed are where the aircraft is more than usually sensitive to external disturbances, or where there is a lack of inherent stability in the aircraft itself. An example of the latter case is provided by the H.P.115 slender wing research aircraft, where a divergent lateral oscillation develops at low flying speeds. In real flight it has been found that this motion can be very easily suppressed with one or two well timed control movements, and to demonstrate this pilots frequently allow the motion to diverge to quite large amplitudes before taking corrective action. Attempts to reproduce this demonstration with non-moving simulation have proved consistently unsuccessful, even with very good visual simulation of the outside world. With the addition of the motion cue, however, the task may be performed almost as easily in the simulator as in flight. This is illustrated by the records shown in Figure 19, taken in flight and on the moving simulator with the same pilot in control.

The validation, wherever possible, of simulator studies by comparison with real flight, in the manner illustrated by these examples, must form a natural and important part of the work of any simulator group, for only in this way can a body of experience be built up which will allow confidence to be placed in simulation studies of future aircraft. Such work also points the way to areas where the development of new simulation equipment will be most profitable.

In the case of the R.A.E. Bedford simulator, for instance, some of the conditions which have proved most difficult to simulate realistically are height control during V.T.O.L. hovering, yaw control during V.T.O.L. hovering, and the representation of sudden yaw disturbances in conventional flight. It is hoped that the development of improved visual simulation devices and the planned addition of yawing motion to the cockpit may help to overcome these difficulties."

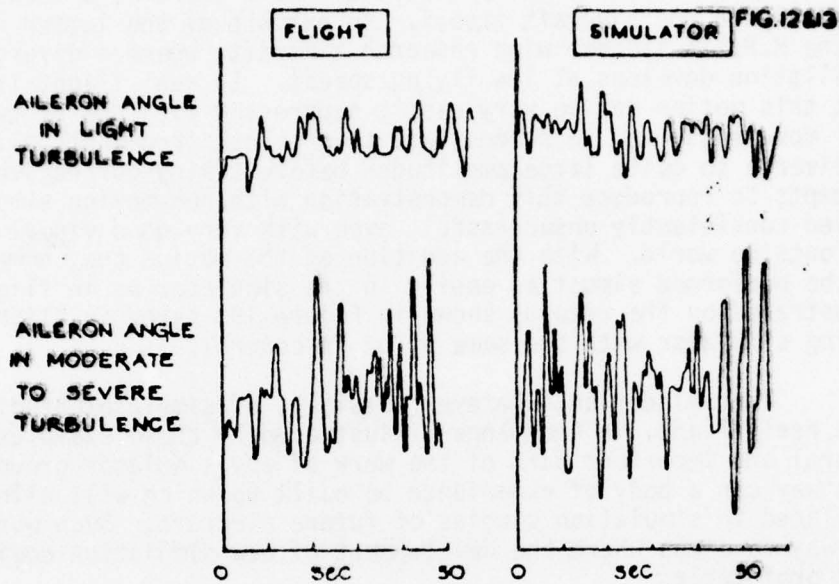


Figure 18. Comparison of Aileron Control Usage in Actual and Simulated Flight Through Turbulence

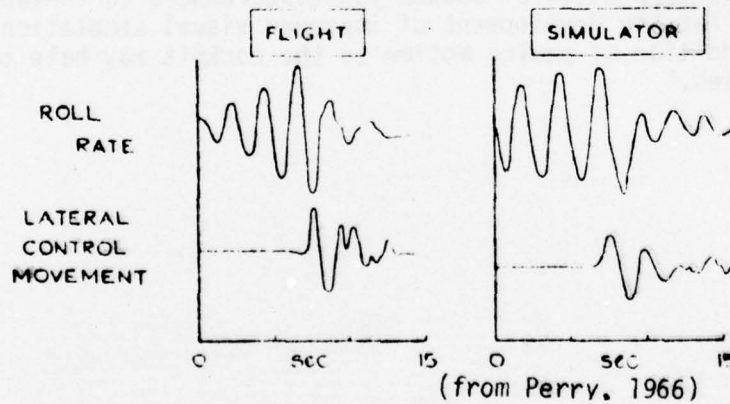


Figure 19. Demonstration of the Pilots Ability to Control an Unstable Lateral Oscillation in Flight and in the Simulator

SECTION VIII

VERTICAL MOTION

A special section has been devoted to this particular degree of freedom of motion because of its importance in vertical take-off and landing (VTOL) and hover controllability. Even in conventional fixed-wing aircraft, the pilot's task in the flare and landing maneuver is to some extent dependent on the perception of vertical motion. In simulation of flight-path control near touchdown, the task appears unrealistically difficult. Deficiencies in visual and motion cue reproduction have been suggested as probable causes of this discrepancy. Bray (1973) performed a study using the Ames Height Control Test Apparatus (HCTA) and concluded that vertical motion cues are used in the landing task, and that they are particularly important in the simulation of aircraft with marginal longitudinal handling qualities.

An interesting approach to helicopter simulation was reported by Caro and Isley (1966). The device used consisted of a captive helicopter mounted on a ground effects machine. It had the approximate handling characteristics of a free-flying vehicle and allowed the students to obtain aeronautical experience not otherwise possible at their level of training.

SECTION IX

COST-EFFECTIVENESS

As cost-effectiveness is an important ingredient in the determination of training effectiveness, and since motion systems constitute a part of simulator costs, it seemed appropriate to include a few reports in this area.

Colonel Ripley, Chairman of the Air Force's Simulator Panel, reviewed the cost of acquiring and operating Air Force simulators in his briefing (1977). In summarizing the costs incurred for procurement, military construction and ten year operating and maintenance costs, his analysis indicated that motion platform procurement represented about 2½ to 7 percent of total simulation program costs.

As indicated by Valverde (1973), "Practical decisions in the use of training devices depend upon compromises between economic and training objectives."

An excellent, recent contribution in this area is the two volume work by Orlansky and String (1977). The first volume concerns the use and effectiveness of flight simulators and the second volume addresses methods of estimating costs of training in simulators and aircraft.

ORGANIZATION	SIMULATOR NAME	ANGULAR PERFORMANCE IN RADIANS & SECONDS							
		ROLL			PITCH			YAW	
		EXCUR	VEL	ACCEL	EXCUR	VEL	ACCEL	EXCUR	VEL
NASA-Ames	Flight simulator for Adv. Aircraft	+0.79	+1.77	+4.0	+0.40	+0.7	+2.0	+0.52	+0.7
NASA-Ames	Six-degree of freedom flight simulator	+0.61	+1.3	+10.0	+0.61	+1.7	+4.5	+0.61	+3.0
NASA-Ames	Height control test apparatus HYCONTA	-	-	-	-	-	-	-	-
NASA-Ames	Moving lab transport simulator	+0.16	+0.22	+4.7	+0.25 -0.10	+0.22	+4.7	-	-
NASA-Ames	Vertical Accel roll device VARD	+0.48	+3.0	+3.0	-	-	-	-	-
NASA-Ames	Vertical motion simulator	+0.38	+0.26	+0.87	+0.44	+0.26	+0.87	+0.51	+0.7
NASA-Langley	Real-time dynamic simulator	Cont	+1.0	+1.0	Cont	+1.0	+1.0	Cont	+1.0
NASA-Langley	Visual motion simulator	+0.38	+0.27	+2.0	+0.50 -0.33	+0.27	+2.0	+0.52	+0.7
USAF-ASD Aeronautical Systems Div	Crew station simulation facility	+0.17	+1.3	+0.88	+0.44 -0.24	+1.7	+0.88	+0.09	+0.7
Naval Training Equipment Ctr	TRADEC	+0.26	+0.35	+3.7	+0.35 -0.18	+0.17	+3.0	+0.31	+0.7
Naval Training Equipment Center	AWAVS	+0.38	+0.26	+0.87	+0.45	+0.26	+0.87	+0.51	+0.7
US Army ECOM	Tactical Avionic System Simulator	+0.26		+0.5g	+0.26		+0.5g	+0.26	
NASA-Marshall	Three-degree of freedom simulator	+0.16	+0.21	+1.0	+0.42 -0.28	+0.21	+1.0	-	-
NASA-Marshall	Six-degree of freedom simulator	+0.38	+0.26	+2.0	+0.52 -0.28	+0.26	+2.0	+0.54	+0.7
USAF Flight Dynamics Lab	LAMARS	+0.43	+1.05	+8.0	+0.43	+1.05	+7.00	+0.43	+1.0
USAF Flight Dynamics Lab		+0.17	+1.3	+0.88	+0.44 -0.24	+1.7	+0.88	+0.09	+0.7
USAF Flight Dynamics Lab		+0.16	+0.22	+4.7	+0.25 -0.10	+0.22	+4.7	-	-

TABLE

(From Burke et al., ...)

RADIAN & SECONDS		SECONDS		TRANSLATIONAL PERFORMANCE IN FEET AND SECONDS									AVAILABLE SYSTEM DIS	
CH	ACCEL	YAW			LONGITUDINAL			LATERAL			VERTICAL			
		EXCUR	VEL	ACCEL	EXCUR	VEL	ACCEL	EXCUR	VEL	ACCEL	EXCUR	VEL		ACCEL
7	+2.0	+0.52	+0.7	+2.0	+4.0	+6.32	+10	+50	+17.0	+12	+5	+8.65	+12.0	Collimated for pilot
7	+4.5	+0.61	+3.0	+3.0	+9.0	+9.0	+7.5	+9.0	+8.0	+9.2	+9.0	+7.5	+8.8	Real world uncollimated for other
	-	-	-	-	-	-	-	-	-	-	+50	+18	+22	Real world collimated
22	+4.7	-	-	-	-	-	-	-	-	-	+2.0	-	+32	Collimated for pilot
	-	-	-	-	-	-	-	-	-	-	+10	+12	+64	Collimated for pilot
26	+0.87	+0.51	+0.26	+0.87	+4.0	+2.0	+16.1	+20	+10	+24	+30	+20	+33	Collimated monitor
0	+1.0	Cont	+1.0	+1.0	+75	+6.0	+6	+6	+4	+6	+20	+6	+6	Monitor or world
27	+2.0	+0.52	+0.44	+2.0	+4.1	+2.3	+19	+4.0	+2.2	+19.2	+2.4 -3.2	+1.3	+32	Color
7	+0.88	+0.09	+0.3	+0.9	-	-	-	+0.5	+1.3	+20	+2.0	-	+25.6	525- & 100 tors from SMK-23's
17	+3.0	+0.31	+0.08	+0.40	-	-	-	-	-	-	+1.0	+1.0	+24	B/W CIG mo picture
26	+0.87	+0.51	+0.26	+0.87	+4.0	+2.0	+16.1	+3.5	+2.0	+19.32	+2.25	+2.0	+25.76	TV project foot diamet Image gener camera/mode
	+0.5g	+0.26		+0.20g	-	-	-	-	-	-	+0.5		+16	3 CRT's wi imating pan
1	+1.0	-	-	-	-	-	-	-	-	-	+1.0	+1.25	+25	48-degree pancake co optics
6	+2.0	+0.54	+0.26	+2.0	+4.0	+2.0	+19	+4.0	+2.0	+19	+2.9	+2.0	+32	Above hard available
5	+7.00	+0.43	+1.05	+3.50	-	-	-	+10	+10	+64	+10	+10	+97	Camera/mod projector;
	+0.88	+0.09	+0.3	+0.9	-	-	-	+0.5	+1.3	+20	+2.0	Yes	+25.6	Non-pupil collimated
2	+4.7	-	-	-	-	-	-	-	-	-	+2.0	Yes	+32	Non-pupil collimated

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TABLE 1. MOVING BASE RESEARCH FLIGHT SIMULATORS OR
MOTION SYSTEMS FOR GOVERNMENT

(From Burke et al., 1975)

SECONDS				AVAILABLE VISUAL SYSTEM DISPLAY	GENERAL COMMENTS
VERTICAL					
ACCEL	EXCUR	VEL	ACCEL		
+12	+5	+8.65	+12.0	Collimated shadow mask for pilot & co-pilot	Three-man cockpit, aural & control loaders
+9.2	+9.0	+7.5	+8.8	Real world for hover, uncollimated monitor for other studies	One man cockpit
-	+50	+18	+22	Real world or collimated monitor	Decommissioned
-	+2.0	-	+32	Collimated monitor for pilot & co-pilot	Three-man cockpit, often set up for two projects, control loaders & aural cues. Previous generation link OFT motion system, perf. is nonsimultaneous.
-	+10	+12	+64	Collimated monitor for pilot & co-pilot	Two-man cockpit
+24	+30	+20	+33	Collimated color monitor	Motion system checkout complete
+6	+20	+6	+6	Monitor or real world	One- & two-man cockpits
+19.2	+2.4 -3.2	+1.3	+32	Color	Link present generation OFT motion system to be outfitted with cockpit
+20	+2.0	-	+25.6	525- & 1000-line moni- tors from modified SMK-23's	Actually 3 separate modified OFT's per- formance data for F-111 system. Other 2 like Ames MCTS - no yaw or lat, radar land mass simulation available, flight dynamics lab has similar system.
-	+1.0	+1.0	+24	B/W CIG monitor picture	Used for trainer research, CAE 4DOF motion system F-111 equiv. cockpit
+19.32	+2.25	+2.0	+25.76	TV projection onto 20- foot diameter dome. Image generation: camera/model or CIG.	Background TV channel is low resolution, wide angle. The target TV channel's narrow FOV presents a high resolution image for insertion into background channel.
-	+0.5		+16	3 CRT's with colli- mating pancake windows	Two upgraded SMK-33's with identical models for visual image gen. two identi- cal cockpits and motion systems.
-	+1.0	+1.25	+25	48-degree B/W TV with pancake collimating optics	Upgraded SMK-23 available as part of lab
+19	+2.9	+2.0	+32	Above hardware available	
+64	+10	+10	+97	Camera/model & earth/sky projector; target A/C	
+20	+2.0	Yes	+25.6	Non-pupil forming, collimated color	Fighter cockpit
-	+2.0	Yes	+32	Non-pupil forming, collimated color	Transport cockpit

ORGANIZATION	SIMULATOR NAME	ANGULAR PERFORMANCE IN RADIANS & SECONDS							
		ROLL			PITCH			YAW	
		EXCUR	VEL	ACCEL	EXCUR	VEL	ACCEL	EXCUR	VEL
Boeing-Vertol	Six-Degree of Freedom Motion System	+0.33	+1.7	+7.2	+0.23	+1.2	+4.2	+0.33	+2.0
Grumman	Three-Degree of Freedom Motion Simulator	+unk	+4.8	+40	unk	+4.8	+40	-	-
Lockheed/Burbank	Flight Training Simulator	+0.35	+0.27	+0.35	+0.50 -0.33	+0.27	+0.52	+0.44	+0.0
Lockheed/Rye Canyon	4 DOF Mo. Sys.	+0.26	+0.30	+0.87	+0.26	+0.26	-	-	-
Vought	Small Amplitude Motion System	+0.35	+1.6	+2.00	+0.18	+0.90	+23	+0.18	+0.0
Vought	Large Amplitude Motion System	+0.26	+0.52	+6.00	+0.19	+0.31	+1.0	+0.19	+0.0
MACDAC McDonnell/St Louis	Moving Base Simulator	+0.79	+1.70	+5.2	+0.52	+0.52	+1.7	+0.52	+0.0
Rockwell International-Columbus	4-Degree of Freedom Dynamic Flight Simulator	+0.70	+35	+21	+0.26	+0.87	+18	-	-
Rockwell International-Los Angeles	HOTRAN	+0.70	+0.35	unk	+0.14	+0.35	unk	-	-
Rockwell Intl., B-1 Division	Transport A/C Sim	+0.26	+0.07	unk	+0.28 -0.14	+0.17	unk	-	-
United Aircraft Research Labs	V/STOL Simulator	+0.52	+0.61	+2.1	+0.78	+0.61	+2.1	+0.78	+0.0
Northrop	Large Amplitude -- Wide Angle Visual (LAS/WAVS)	+0.35	+1.0	+5.0	+0.35	+1.0	+17	+0.35	+1.0
Northrop	3-Axis Flight Simulator	Yes			Yes			Yes	
MACDAC Douglas/Long Beach		+0.54	+0.62	+7.8	+0.58	+0.56	+7.8	+0.69	+0.0

<u>+4.8</u> <u>+40</u>	- - -	- - -	- - -	<u>+3.0</u> <u>+7.0</u> <u>+97</u>	Unknown
<u>+0.27</u> <u>+0.52</u>	<u>+0.44</u> <u>+0.35</u> <u>+0.35</u>	<u>+4.2</u> <u>+2.0</u> <u>+16</u>	<u>+4.9</u> <u>+2.6</u> <u>+16</u>	<u>+2.8</u> unk <u>+24</u>	Cine Pro Servoed
<u>+0.26</u> -	-		<u>+1.25</u> <u>+1.25</u> <u>+6.4</u>	<u>+1.0</u> <u>+1.0</u> <u>+32</u>	B/W proj collimat
<u>+0.90</u> <u>+23</u>	<u>+0.18</u> <u>+0.90</u> <u>+22</u>	- - -	<u>+1.0</u> <u>+5.4</u> <u>+144</u>	<u>+1.0</u> <u>+5.4</u> <u>+176</u> <u>-112</u>	20 ϕ spher for proj or camer
<u>+0.31</u> <u>+1.0</u>	<u>+0.19</u> <u>+0.28</u> <u>+2.0</u>	- - -	<u>+5.0</u> <u>+10</u> <u>+19.3</u>	<u>+10</u> <u>+20</u> <u>+62.4</u>	
<u>+0.52</u> <u>+1.7</u>	<u>+0.52</u> <u>+0.52</u> <u>+1.7</u>	- - -	<u>+5.0</u> <u>+5.8</u> <u>+32</u>	<u>+10</u> <u>+13.5</u> <u>+100</u>	25" coll for colo or CGI
<u>+0.87</u> <u>+18</u>	- - -	- - -	<u>+2.0</u> <u>+10</u> <u>+22</u>	<u>+10</u> <u>+14</u> <u>+161</u>	TV monit camera/m project
<u>+0.35</u> unk	- - -	- - -	- - -	<u>+0.50</u> <u>+0.83</u> Unk	Point li be able from cam
<u>+0.17</u> unk	- - -	- - -	- - -	- - -	SMK-23 @ optics b or proje
<u>+0.61</u> <u>+2.1</u>	<u>+0.78</u> <u>+0.65</u> <u>+2.5</u>	<u>+5.0</u> <u>+3.0</u> <u>+32</u>	<u>+5.0</u> <u>+3.0</u> <u>+32</u>	<u>+2.5</u> <u>+3.0</u> <u>+32</u>	TV monit
<u>+1.0</u> <u>+17</u>	<u>+0.35</u> <u>+1.0</u> <u>+50</u>	- - -	<u>+10.1</u> <u>+10</u> <u>+51</u>	<u>+10.4</u> <u>+13</u> <u>+97</u>	Various camera m horizon
	Yes				200 Hori source
<u>+0.56</u> <u>+7.8</u>	<u>+0.69</u> <u>+0.70</u> <u>+7.8</u>	<u>+5.4</u> <u>+5.9</u> <u>+48</u>	<u>+5.6</u> <u>+6.0</u> <u>+46</u>	<u>+3.5</u> <u>+3.3</u> <u>+53</u>	Collimat monitor

2

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TABLE 2. MOVING BASE RESEARCH FLIGHT SIMULATORS OR MOTION SYSTEMS FOR INDUSTRY

(From Burke et al., 1975)

SECONDS				AVAILABLE VISUAL SYSTEM DISPLAY	GENERAL COMMENTS
ACCEL	VERTICAL				
	EXCUR	VEL	ACCEL		
+29	+0.42	+2.2	+65	CGI, 38 X 53, B/W 600 TV lines, collimated	One-man cockpit, control loaders
-	+3.0	+7.0	+97	Unknown	
+16	+2.8	unk	+24	Cine Projector with Servoed speed & optics	Apparently identical to Langley 6-deg motion base, built as L-100 trainer; use for research is potential
+6.4	+1.0	+1.0	+32	B/W projector or collimated monitor	Two Camera/Model Vis. Image Gen.
+144	+1.0	+5.4	+176 -112	20φ spherical screen for projection of CGI or camera model images	Motion system can mount any of several 1-man or 2-man cockpits. Control loaders available
+19.3	+10	+20	+62.4		
+32	+10	+13.5	+100	25" collimated monitors for color camera/model or CGI	Boom-type system, generally built for fighters
+22	+10	+14	+161	TV monitor & large camera/model system can project horizon slide	Performance numbers are specs. boom-type system
-	+0.50	+0.83	Unk	Point light source, must be able to mount monitor from camera model	Interchangeable cockpits, made for VTOL hover
-	-	-	-	SMK-23 @ upgraded optics by monitor or projector	Transport cockpit
+32	+2.5	+3.0	+32	TV monitors @ CGI	Franklin Inst. Pilot Model of Singer-Link 6 DOF
+51	+10.4	+13	+97	Various including camera model & horizon projector	One- & two-man interchangeable cockpits with control loaders
				200 Horiz point light source	
+46	+3.5	+3.3	+53	Collimated color monitor	Transport cockpit in-house built, Franklin Institute-type motion

TABLE 3. G-SEAT EVALUATIONS (POSITIVE RESULTS)

TASK	TYPE OF SEAT	SOURCE	COMMENTS
Takeoffs, GCA's, 360° overhead traffic patterns, slow flights, and aileron rolls.	ASPT (T-37 cockpit) 31-bellow pneumatic G-seat.	Irish, Grunzke, Gray and Waters (1977)	Performance was generally superior when the G-seat was functional as compared to when it was not.
Takeoffs, Ground Controlled Approaches (GCA), Landings, 360° overhead traffic patterns, slow flights, and aileron rolls.	ASPT	Waters, Grunzke, Irish & Fuller (1976)	The G-seat improved performance consistently, particularly under the limited visual field of view (FOV) condition. Significant first order interactions emerged between FOV and G-seat factors with the G-seat most beneficial to system output measures with the limited (36°x48°) FOV.
DMS using F-14 simulation tracking a target maneuver, at a constant range of 1500 ft, with a 3g wind up-turn at a constant air-speed of 325 kts.	Four cell seat using a thin air cushion with highly responsive pressure control; seat-on (seat-off).	Ashworth, McKissick, & Martin (1977)	Statistical analysis of data indicates that the pilot receives information from the seat which allows more precise control of the simulated aircraft. Pilot subjective evaluation supports this conclusion. (NASA Langley's Differential Maneuvering Simulator.)
Rate realism and identify following maneuvers: Climb, dive, turn right, turn left, climbing right turn, diving left turn.	DYNASEAT (Trademark, Goodyear Aerospace Corp.)	Barrett, Cabe, Thornton & Kerber (1969)	Seat motion significantly increased rated realism over no motion condition for the series of six maneuvers. With eyes closed, correct identification of maneuvers averaged 85% and rated confidence in judgments averaged 76%.

TABLE 3. G-SEAT EVALUATIONS (POSITIVE RESULTS) (Contd)

TASK	TYPE OF SEAT	SOURCE	COMMENTS
Low Target gunnery tracking and a loop.	SAAC	Stark (1976)	<p>The seat was found to make major contributions in five areas relevant to air combat simulation: (1) control of simulator to $\frac{1}{2}g$, (2) coordinated use of available energy by simulation of thrust cues in longitudinal acceleration, (3) provided better cues in the backside of the loop, (4) sustained g, (5) tracking.</p> <p>G-seat gains (inches of displacement per "G") were set informally during the earlier pilot evaluations, to levels which seemed natural to the pilots and which appeared to provide useful cues. Later in the evaluation gains were set to two higher values, 1.5 and 1.75 times the original. The 1.5 gain appeared to provide more relevant control cues than either the original or the 1.75 gain.</p>
(Info not available)	(Info not available)	Taylor & Gerber, et al (1969)	<p>Flexman reported that some experiments were performed in England using a Redifon simulator that indicated an improvement in training when motion of the simulator was accompanied by "G-seat" forces. Details of the seat and the experiment are not available.</p>

TABLE 3. G-SEAT EVALUATIONS (NEGATIVE RESULTS) (Contd)

TASK	TYPE OF SEAT	SOURCE	COMMENTS
Aileron roll, barrel roll, loop, GCA, and 360° overhead pattern.	ASPT G-seat: (1) fully operational; (2) only seat pan operational	Irish & Buckland (1978)	Presence or absence of the G-seat variable did not appear to effect changes in pilot performance.
81 tasks for full mission air-to-ground weapons delivery, including takeoff and landings, formation flights, strafing and bombing, etc.	(1) ASPT G-seat (2) SAAC G-seat/suit system	Hutton, Burke, Englehart, Wilson, Romaglia & Schneider (1976)	(1) Page III-25: "The G-seat did not appear to offer true positive or negative 'G' cues. The seat inflation seemed unnatural and excessive. As a result, the pilots were unable to control their 'G' scheduling using real-time kinesthetic cues." (A technical improvement was proposed by modifying the G-seat algorithms to present cues specifically structured for the air-to-ground task.) (2) Page III-100: "G-seat and suit inputs appeared to lag that anticipated by the pilots. The inflation and deflation rates appeared to be too slow. The G-seat seemed to apply pressure unevenly in instances where the pilots felt that the pressure inputs should have been smooth and evenly distributed. The G-seat cue for afterburner power appeared unrealistic to several of the pilots. (Lags are due to hardware design; inherent to the pneumatic valves used. Cue quality is primarily a function of programming.)

TABLE 3. G-SEAT EVALUATIONS (NEGATIVE RESULTS) (Contd)

TASK	TYPE OF SEAT	SOURCE	COMMENTS
Compensatory tracking: two aircraft at same altitude and air-speed. Pilot to anticipate and compensate for vertical disturbance of target aircraft.	Basic Singer seat (ASPT) without side panels leaving 23 bellows	Showalter, T. W. (1978)*	This comparative evaluation of G-seat and motion cueing effects monitored disturbance input and control column output. The results showed: (a) no difference in phase shift as a function of the cueing system used, (b) platform motion lowered the amplitude ratio (between 3 and 6 rad/sec.), (c) the G-seat did not reduce the amplitude ratio, (d) when used together, the G-seat would nullify the effects of the platform motion.
1. Approach and landing with wind shear (KC-135 Simul.) 2. Precision turn 3. Outboard engine failure on takeoff	Basic Singer seat (ASPT) without side panels	Ripley, R. (1977)	According to the results of the NASA KC-135 study designed to determine if the G-seat is an adequate cueing device for large aircraft, incorrect control inputs were common when the G-seat, was used alone. These results indicate that this G-seat as currently designed, provides no training benefit for large aircraft (cf., Showalter & Parris, 1978) (Phase I of study; Cueing characteristics in training.)

*Report unpublished as yet. Comments from personal communication with author.

TABLE 3. G-SEAT EVALUATIONS (EQUIVOCAL RESULTS) (Contd)

TASK	TYPE OF SEAT	SOURCE	COMMENTS
Formation flight: maintain "finger-tip" position off right wing of lead aircraft.	ASPT G-seat	Ricard, Cyrus, Cox, Templeton, & Thompson (1978)	(1) Pilot rating: No difference between the subjective impressions obtained from the visual display alone and with the G-seat added. (2) Observer rating: Flights were most controlled when the G-seat was activated. (3) <u>Objective measures</u> : No difference with G-seat on or off.
1. Approach and landing with wind shear (KC-135 Simul.) 2. Precision turn 3. Outboard engine failure on takeoff	Basic Singer seat (ASPT) but without side panels (23 bellows)	Showalter, T. W. and Parris, B. L. (1978)*	Performance comparisons using G-seat only, motion only, and fixed-base only. Results indicated: For Task 1: Platform motion improved performance on most difficult trials, whereas, G-seat or fixed-base decreased performance on these trials. For Task 2: Effects from G-seat or platform motion were difficult to interpret; probably negligible. For Task 3: Platform motion consistently improved performance. G-seat only condition was better than fixed-base but not as good as platform motion.
Head down terrain following & general maneuvering involving pull-ups, push-overs, and tight turns.	Cranfield G-seat (developed from a basic Martin-Baker Lightning ejection seat). A G-suit was used to complement the seat.	Matthews & Martin (1978)	In the absence of a visual system, a flight record in the form of flight path angle demand was used to drive a director bead on the simulator artificial horizon. This gave command signals in the pitch plane requiring maneuvers in the range of 0 to 3g. The simulation did not have heading commands. The three cues provided by the seat were shoulder strap pressure, eye height change, and buttocks pressure change.

*Report unpublished as yet. Comments from personal communication with senior author.

TABLE 3. G-SEAT EVALUATIONS (EQUIVOCAL RESULTS) (Contd)

TASK	TYPE OF SEAT	SOURCE	COMMENTS
			While many comments on individual aspects of the G-seat were favorable, most pilots found deficiencies in the interaction of cues. The majority of pilots thought that the seat had no effect on the closed loop terrain tracking task. There was considerable agreement on the importance of the G-suit in complementing the G-seat.
			As a result of the evaluation, the current seat appears to be accepted by the pilots.

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Flight in turbulence	Turbulence	Hitchcock and Chambers (1965)	In the dynamic simulation, the number of control movements was greater and the magnitude of bank angles occurring was less than in the static simulation.
LAHS Flight	Clear air turbulence roll, pitch and yaw	Buckout, Sherman, Goldsmith & Vitale (1963)	Motion does "appear to contribute" to training effectiveness. Training in turbulence in simulators is desirable since (1) natural turbulence is scarce and (2) it is dangerous to fly LAHS. Motion in roll, pitch and yaw provided significantly enhanced transfer to the criterion task in the simulator as compared to the performance of people trained without motion.
Train to fly marginally stable aircraft	PIO	Rathert, Creer & Douvillier (1959)	PIO can be introduced in moving base as in actual aircraft.
Train to fly marginally stable aircraft	Engine out	Spitzer & Rumsey (1966)	Reaction time on a moving base simulator was one-half that found on a fixed base simulator.
Transition in VTOL aircraft	Pitch & roll	Heinle (1966)	Without cockpit motion, the transition was very difficult to perform, even in the limited 3 DOF case of the longitudinal mode only, because of the multiplicity of quantities which had to be monitored. The addition of roll and yaw modes and their visual indications, to give 6 DOF of fixed base simulation made the task impossible. It was necessary to add pitch and roll cockpit motions to achieve satisfactory performance.

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
VTOL hover of slender delta con- figurations	Yaw	Perry (1962)	Lack of physical yaw motion was identified as the reason for discrepancies between flight and simulator findings.
Evaluat- ing con- trols & displays		Creer, Stewart (1959) Merrick & Drinkwater Douvillier (1960)	Displays and controls judged to be superior in fixed-base simulation were found to be inferior in both moving-base and flight.
Evaluat- ing con- trols		Graves, Bailey & Mellen (1962)	Control technique changed from bang-bang in fixed base simulator but not in flight.
Other than normal condition approaches		Cooper (1963) Huddleston (1965) Rathert, Creer & Douvillier (1959) Sadoff & Harper (1962)	The fixed-base simulator is reliable only for stable aircraft, with little or no turbulence. For this task (abnormal landings), fixed-base simulation is inadequate. From Cooper, engine out landings may be uncontrollable in fixed-base simulators, but relatively easily accomplished in moving-base simulators. "It cannot be said that motion is required for takeoff and landing research, but motion is desirable to provide realism and improve adaptation to the simulator. Motion is required, however, for properly assessing the marginally controllable handling characteristics and the physical effects of distractive motions themselves."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
STOL handling qualities, landing	Roll, translation lateral	Clousing (1964)	"It would appear that translational lateral travel combined with bank and appropriate washout provisions may be required to adequately study lateral-directional problems of STOL operation of low speeds." "Important factors in ground simulation are: ...sophisticated motion simulation and control characteristics duplication in STOL landing approach studies."
Failure of ILS	Roll	Young (1967)	Pilot recovery times following a failure in a caravelle blind landing system increased nearly 100 percent when motion cues were eliminated from the simulation. "Even though stability is not a major problem in this case, the motion cues are important because they rapidly alert the pilot to sudden changes in attitude rates." Helicopter pilots use motion cues for attitude stabilization. The use of motion cues appears to be directly proportional to pilot experience with more skillful pilots benefiting more from motion cueing.
Pitch-up	Pitching acceleration	Cooper (1957)	"Comparison of ground simulation and flight tests indicate that pilot control is quite different when their only stimulus is visual as on the ground, from their reactions when they also have motion stimuli in the air."
Longitudinal control	Pitch and roll	Sadoff, McFadden & Heinle (1961)	Adding only angular motion to the visual cues provided enough cueing to compare favorably with flight.
Formation flight	Roll, pitch, yaw	Brown, Johnson and Mungall (1960)	Motion cues enabled pilots to perform a precise formation flight task over a range of longitudinal stability conditions. The value of motion cues in enhancing performance compared to no motion was particularly dramatic when stick force gradients were zero with visual.

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Carrier approach and landing		Ruocco, Vitale Benfari (1965)	With visual. Transfer of training with both the transfer and training tasks performed in the simulator. Motion cueing during training significantly improved transfer task performance. Motion serves as an alert mechanism that alerts the pilot to changes of state of the aircraft and prompts increased attention to visual cues, in certain cases motion may provide useful information that the pilot uses directly in vehicle control.
-	Disturbance	Borlace (1967)	In simulation without motion, a pilot is deprived of fast acceleration feedback and so builds up simulator habit patterns which are not equivalent to those demanded in the air. Pilots in simulators, with motion systems, perform their tasks more precisely, with less time lag, and with higher frequency components in the control motions than they do in simulators without motion systems. The way pilots perform in simulators with motion cues is closer to the way they perform in the aircraft. Training in simulators without motion tends to have a negative initial or first shot transfer to the aircraft.
Landing	Vertical acceleration	Bray (1973)	To assure vertical motion cues of the desired fidelity in landing, a simulator must have excursion capabilities of at least plus or minus 20 feet. (These requirements are for a large transport type research simulator designed specifically for the landing task.)
Tracking	Perturbations, side gust loading	Perry & Naish (1964)	Continuous motion cueing makes the pilot more aware of the requirements for, and the consequences of, control inputs and enables him to perform maneuvers more precisely, quickly, and more economic control usage following a disturbance. The need for motion cueing thought to vary with aircraft characteristics being simulated. Time lags for the pilot ranged from 17 seconds with no motion to about one-half second when motion cues were available. A visual display system was used.

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Tracking terrain following	Pitch	Besco (1961)	With and without motion, found motion cues facilitated precise tracking performance. With visual.
Night approach & landing with crosswind		Wendt, Stark, Simon & Cohen (1961)	CGI Visual. "Without motion, there was a tendency to undershoot the runway; however, lateral deviations were kept small. With motion, the simulated aircraft touched down significantly later; at the same time, the lateral correction was less adequate." "Evidently, motion alerted the pilot to certain more critical problems and caused a different allocation of his information processing capabilities." (Smode, 1971)
Helicopter		Matheny, Dougherty & Willis (1963)	Motion cues are more closely coupled to the pilot than are visual cues. The proprioceptive senses lead the visual senses in perceiving the development of certain conditions of flight. When the angular acceleration reached 25 degrees per second, the motion cues preceded the visual cues by 0.4 to 0.5 seconds. Motion simulation systems, which exhibit transient accelerations or unrealistic phase differences between motion and visual stimuli, may provide cues to response which are inappropriate to the task of the operator. Such faults in motion simulation may be equally serious for those situations in which the simulator is used as a training device as for those in which it is used as a design and evaluation tool.
Instrumentation tracking helicopter	Roll, pitch, yaw and heave	Fedderson (1962)	Skilled pilots trained on a moving base simulator achieved a greater rate of acquisition of proficiency and a higher level of performance compared to fixed-base training conditions. Similar results were demonstrated by naive subjects. It was concluded that a training device incorporating these four degrees of freedom would enhance the rate of proficiency attainment and increase the amount of transfer obtained.

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Brake failure	Yaw	Cohen (1970)	With the motion system turned off, it took the pilots more than 7 seconds to operate the emergency braking system. With motion on, it took from 1.5 to 3.0 seconds. "Considerable evidence is adduced that motion in flight simulators produces significant training benefits, but there is a scarcity of data on the consequences of different degrees or methods of motion simulation."
Landing	None	Brown (1970)	'It is concluded that some form of cockpit motion must be necessary to achieve realistic landing performance.' (This study did not employ any motion.)
Training pilots	Roll, pitch, yaw	Caro, Jolley, Isley and Wright (1972)	Motion makes the training task appear more realistic to the trainee and thus enhances his motivation to use the device. Cockpit motion, preferably in the pitch, roll and yaw dimensions, is considered to be an essential characteristic for a primary contact trainer. "Motion cueing enables a pilot to detect changes in aircraft attitude and speed more rapidly than might otherwise be possible." "Motion is particularly useful to experienced pilots who have learned to attend the motion cues associated with the onset of systems malfunctions. Consequently, motion must be more faithfully reproduced for them in a training device than for inexperienced pilots. Motion appears to have a minor, but useful effect upon development of skills in control of the aircraft on instruments and motion is probably quite useful for the recognition of unusual flight conditions and malfunctions. "However, in view of the value motion may provide for recognizing the onset of unusual conditions and malfunctions plus the greater trainee acceptance of devices incorporating motion, the cost of a simple motion platform probably is justified."
Instru- ment	Roll, pitch, yaw	Cutler (1966)	"The lack of cockpit motion cues in early simulators gave rise to excessive pilot scrutiny of instrument behavior fidelity."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

TASK	PRIMARY STIMULUS	SOURCE	COMMENTS
Engine failure KC-135	Six DOF	DeBerg, McFarland & Showalter (1976)	"Results indicate: (a) The superiority of training effectiveness with visual simulator systems, (b) The enhancement of training effectiveness by including a motion system in the training simulator, and (c) The synergistic improvement in training using both motion and visual systems together."
Aircrew training	-	Dunlap & Anderson (1974)	"This research tends to show the inner ear is a less reliable sensing mechanism than the muscular support and body pressure sensing mechanisms. While less reliable, the inner ear responses to motion are important in that the absence of these cues in the presence of other motion cues, such as those perceived by the eye from a visual display, can produce nausea in the experienced pilot conditioned to combinations of sensory stimuli. Their absence in a simulator could also lead to disorientation in the real air situation for a UPT student conditioned by less complete combinations of motion cues."
Training pilots	-	Gerathewohl (1969)	"Part-task simulators are usually less expensive and of lower fidelity than whole-task simulators, they can be very useful for the learning of specific tasks. However, their shortcomings, as clearly demonstrated by Adams can be traced back to the lack of fidelity, particularly in simulating motion. It seems that the whole task simulator derives its advantages as a training device primarily from the incorporation of motion cues, if the addition of complex motion vectors increases the fidelity of the simulation and does not result in spurious stimuli."
Research & de- velopment simula- tion	Roll, pitch, heave & sway	Graham (1968)	"The study concludes that moving base simulation is required and at least four degrees of freedom -- pitch, roll, vertical translation, and lateral translation be provided."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
-	Pitch, roll, heave	Huddleston (1966)	"From a review of available literature, largely American in origin, it is apparent that some aspects of both the transfer of aircrew training and the applicability of research data can be influenced by the cockpit dynamics of the simulator on which the work was done."
Flight training	Roll, pitch and yaw	Huddleston & Rolfe (1971)	"Probably vestibular and kinaesthetic cues follow in importance after vision as far as the flying task is concerned. Few workers now need convincing that whole body motion is important. Without motion, experienced pilots are often able to achieve a level of performance which is perfectly acceptable, but an examination of their control behavior shows that their performance is achieved using a strategy entirely different to that utilized in a dynamic environment. It is also possible to argue from comparative studies of the same pilot's response in flight and in a simulator with and without motion cues (Rolfe, Hammer-ton-Fraser, Poulter, and Smith, 1968) that the presence of cockpit motion produces patterns of control response more closely related to those employed in flight. This latter finding is supported by other research (Feddersen, 1962; Trembley, Brown, and Futterweit, 1964; Staples, 1970).
Flight training	6 DOF	Hunter (1968)	Meyer (1967) asked pilots converting to the DC-8 aircraft to assess which features of the simulator affected its value as a training device and relate them to particular aspects of the training programme. The factor most commented upon included acceleration forces, vibration, roll, pitch and yaw motion.
			"Both the airlines and aircraft manufacturers further agree that flight simulators should be able to duplicate the pilots sensations or kinaesthesia of at least the initial acceleration and changes of aircraft attitude."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
V/STOL ground effects	-	Kennelly (1959)	With visual. "Since this field places a premium on pilot response, we felt that the angular acceleration and velocities of the cockpit would be a particularly useful feature of this study."
Air-to- Air gunnery	-	Klier & Gage (1970)	With visual display. The researchers varied the frequency bandwidth of their motion equipment. "Results of performance (e.g., percent time on target) indicated or tendency for the order of conditions from best to worst to be 0-2.5Hz, 0-1.0Hz, 0-3.5Hz, 0Hz. Simulator motion produced better accuracy performance than no motion." In general, the results of this study appear to confirm indications in previous studies that simulator motion need not be a faithful reproduction of real-life motion in order to provide essential motion area.
-	Roll, pitch, yaw & heave	Matheny, Lowes & Bynum (1974)	"With respect to correlated motion, it was found that it differs significantly from uncorrelated motion. Although the pilot's control of system output was the same under uncorrelated and correlated motion conditions, a different technique was used by the pilots under the two conditions."
Light helicopter training	Roll, pitch, yaw & heave	Matheny & Wilkerson (1970)	"With regard to the incorporation of motion into ground-based training devices for the light training helicopter, the evidence indicated that training not only proceeds faster in the trainer but a greater amount of transfer is obtained when the trainer has incorporated the motions of pitch, roll, yaw and heave. The authors feel a cost analysis should be conducted, for example, "Fedderson (1962) that approximately six hours in fixed base simulator plus some 20 minutes in the helicopter will produce a level of proficiency equivalent to four and one-half hours in a moving base simulator with approximately 10 minutes in a helicopter."
Training tasks	5 DOF no surge	Matthews (1970)	"Physiological cues are normally concerned with the reaction of the pilot to the flight of the aircraft. These are mainly motion cues associated with angular and translational motion."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
R&D simulation	6 DOF	Schmidt & Conrad (1970)	"An important aspect of many piloted flight simulators is their ability to provide realistic motion cues."
Energy maneuvering	6 DOF	Stark & Wilson (1973)	"Visual cues and motion in all six degrees of freedom are required to permit control without excessive instrument reference. Cues to g forces, sustained acceleration, buffet and vibration are required to permit efficient control within structural limits."
Instrument tracking	Roll, pitch	Williges & Roscoe (1973)	It was concluded that the presence or absence of motion cannot only affect absolute levels of performance, but different orders of merit among displays can occur. Specifically, inappropriate cockpit motion may be more misleading than no motion, whereas limited motion in pitch and roll that corresponds closely to the angular accelerations encountered in flight may be sufficient to produce generalizable research data on the relative merits of flight displays. The effect of motion cues on pilot performance is complex, and potential interactions among visual motion cues, pilot workload, pilot experience, and the degrees and fidelity of motion simulation need further investigation.
UPT	6 DOF	Odierna (1970)	"From this study it is concluded that UPT 7590 flight simulators should incorporate a six-degree-of-freedom synergistic motion system with a 48-inch stroke."
VTOL Hover	Yaw	Perry (1965)	"Motion is felt to keep the pilot informed, almost subconsciously, of disturbance to aircraft's trimmed state. Lack of yaw motion is almost certainly reason for discrepancies between flight and simulator findings in studies of VTOL hover and slender delta yaw characteristics."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Instru- ment flight maneuvers from pri- vate pilot curriculum	Roll, pitch (Gat-2)	Jacobs & Roscoe (1975)	Pilot performance, in terms of errors committed, improved in the simulator when either normal washed-out motion or randomly reversed roll cue motion were used, however, less time required, errors committed and trials to criterion were obtained for the normal washout than fixed base which was superior to randomly reversed roll cueing motion.
Various	Various	Flexman (1966)	"Since 1955, a number of research studies have been accomplished by the Air Force, Navy, Army, NASA and various university groups concern- ing the value of motion in flight simulators. In every case known to the authors, the desirability for including motion in flight simulators and trainers was reaffirmed...."
Litera- ture survey	-	Horowitz & Wells (1958)	On the basis of the survey, the authors recommend that cockpit motion capabilities be included in flight trainers.
Various	-	Meiry (1965)	"A considerable reduction of operator phase lag is noticed for the moving simulation relative to the fixed-base one." In his conclusion he reports, "the operator is able to reduce his delay time in a manual control system where his semi-circular canals provide information on the vehicle motion, compared to the delay in a system with visual display only."
Training simula- tion	6 DOF	Gibino (1968)	"Hence, since the eye requires a longer time interval to discern in- strument movements, fixed-base cockpit studies have shown that pilots tend to over control the simulator," "Sophisticated flight simulators should not be purchased by the United States Air Force without motion systems of comparable sophistication."

TABLE 4. LITERATURE SURVEY RESULTS -- FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Comparison of displays	Roll, pitch	Ince, Williges & Roscoe (1975)	"Overall performance in the simulator under wash-out banking and sustained pitching motion were reliably better and more representative of actual flight performance than performance without motion cues. The order of merit of the experimental displays, ..., also corresponded most closely to their order of merit in flight when the simulator was operated with wash-out motion, thereby clarifying earlier findings by Jacobs, Williges, and Roscoe (1973)." Taken from Jacobs and Roscoe (1975).

TABLE 5. LITERATURE SURVEY RESULTS -- NOT FAVORING THE EFFECTS OF COCKPIT MOTION CUEING

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Formation Pitch flight		Brown & Johnson (1959)	A one degree-of-freedom (pitch) motion base was used to evaluate various amounts of aircraft stability, stick force and position gradients. "The differences in performance as measured with and without the pitching motion were very small for one pilot and negligible for the other. Therefore, the pitching-motion cues were not considered to be of importance in close-formation flying."
Space flight	-	Johnson (1963)	"The astronauts report that display motions alone in fixed-base simulation constitute a surprisingly good approximation of combined instrument and body movements under weightlessness in space. Linear accelerations during launch and re-entry can be reproduced satisfactorily as a part-task on the centrifuge and, therefore, need not be provided in the flight trainers."
Takeoff, GCA, aileron rolls 360° overheads	6 DOF & roll, pitch, yaw	Waters, Grunzke, Irish & Fuller (1976)	An ASPT Study. "System performance was significantly better with no motion vs either 3 degrees or 6 degrees-of-freedom motion. Pilot inputs were significantly smoother under no motion conditions. The g-seat improved performance consistently, particularly under limited FOV."
Weapons delivery air to surface	6 DOF	Gray & Fuller (1977)	"It is impossible to prove the null hypothesis, but the results of the study show unequivocally that six degree-of-freedom platform motion did not enhance the training value of the simulator." ASPT study with visual.
(Review of Koonce study)		Hopkins, C. O., (1974)	Dr. Hopkins concluded from Dr. Koonce's experiment that, "Certainly, there is no evidence that simulator motion of either of the two types used enhanced transfer of training from the simulator to the aircraft. On the contrary, it may very well be the case that with simulator motion, pilots learn to respond to acceleration cues that may not be present in aircraft flight because much aircraft motion involves accelerations that are below detection level."

TABLE 5. LITERATURE SURVEY RESULTS -- NOT FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
(Review of Koonce study)		Roscoe, S. N.; (1974)	Dr. Roscoe apparently reached the same conclusion as Hopkins (1974) and stated: "Apparently, pilots trained in moving simulator cockpits learn to depend upon acceleration cues, which they must learn not to depend on in the air because much airplane motion occurs at subliminal acceleration levels." Both Hopkins and Roscoe maintain that performance in the aircraft was not affected by the presence or absence of motion in the simulator.
UPT	6 DOF	Woodruff (1976)	An ASPT study. Both motion and no-motion had equal transfer of training.
84 Transfer of training contact, approach & landing skills	6 DOF	Martin & Waaag (1978)	Analyses of the data revealed the following findings: (a) no differences in simulator performance emerged between the motion and no-motion groups on either IP ratings or automated score, (b) significant learning occurred during simulator training for both groups, (c) no difference in performance emerged between the motion and no-motion groups for any of the tasks on the two special data sorties flown in the T-37, (d) no significant differences were found between the motion and no-motion groups in the task frequency data, although there was a trend for the motion group to perform slightly better, and (e) the two groups trained in the ASPT performed significantly better than the control group through the solo phase of training on all of the more advanced tasks.
	Roll, pitch, heave & 6 DOF	Irish, Grunzke, Gray & Waters (1977)	"The platform motion variable had a striking impact upon pilot performance. Almost invariably, the addition of platform motion cueing produced a concomitant decline in performance."

TABLE 5. LITERATURE SURVEY RESULTS -- NOT FAVORING THE EFFECTS OF COCKPIT MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Aileron roll, barrel roll, loop, GCA & 360 overhead	6 DOF	Irish & Buckland (1978)	Expert pilots tend to perform better with wider FOV and without platform motion for the maneuvers investigated in this study.
General various	Various	Cyrus (1978)	This report reviews the literature as it relates to the use of platform motion. He concludes; for most tasks platform motion is not required to produce rapid, efficient, economical training.

TABLE 6. LITERATURE SURVEY RESULTS -- QUESTIONING THE EFFECTS OF MOTION CUEING

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Closed loop tracking one & two axis	Pitch, yaw, roll	Bergeron (1970)	Tests were designed to define areas where motion cues were beneficial in controlling tracking tasks. The results indicate that "addition of motion had little or no effect on the control of the single-axis tasks that were tested, however, motion did make a difference in the more difficult two axis tasks. A reduction in the scale of motion, in the two axis tasks, as little as 1/4 motion scale, produces results comparable to when full-scaled motion was used."
VTOL	Six degrees of freedom	Feddersen (1961)	The motion-cue trained group performed better initially than did the no-motion group but the differences disappeared by the end of the sixth trial flying session (in the helicopter). Based on this, it appears that a no-motion simulator trained group can quickly learn to use the motion cues in the aircraft (assuming relevancy with visual cues and equivalence in response dynamics between simulator and aircraft).
X-15 re-entry	Centrifuge	Holleman & Wilson (1963)	"The pilots indicated that the centrifuge simulations were worthwhile and necessary in gaining a feeling for high accelerations. However, they felt that after experiencing the acceleration effects in the centrifuge, the fixed-base simulator was adequate preparation for the extreme X-15 missions."
Flight training	Roll, pitch, yaw	Johnson (1970)	"I question the wisdom of the apparent present day rush to buy six axis motion equipment. We do require realistic simulation of the asymmetric swing on landing and takeoff, also pitch changes during takeoff, overshoot and approach to stall and in air turbulence."
X-15 space flight	Centrifuge	Brown	The most frequently heard justification for the addition of motion cues is that they afford an increase in realism. When this justification is applied to situations in which motions are not extreme, it must be examined very carefully. There is very little satisfactory evidence to validate the assumption that the addition of motion cues in a laboratory simulator actually increases realism.

TABLE 6. LITERATURE SURVEY RESULTS -- QUESTIONING THE EFFECTS OF MOTION CUEING (Contd)

TASK	PRIMARY STIMULUS	SOURCE	COMMENTS
Five maneuvers (IFR) & five scaled down (VFR) all analog performed in a Singer-Link GAT-2 (no visual) same maneuvers were then flown in a Piper Aztec	Pitch & roll 1. sustained J. M.; linear, (1974) scaled down 2. washout 3. no motion	Koonce, J. M.; (1974)	This study was concerned with the reliability of instrument flight checks in a modified Link GAT-2 simulator and the predictions that could be made from them to performance in a Piper Aztec aircraft. Although Dr. Koonce did not design his experiment to examine transfer of training, he does make the statement under "Conclusions" (page 87): "Simulator motion tends to increase the subject's acceptance of the device, lower performance error scores, and reduce workload on the subjects and the observers through the aiding effects of the motion onset cues. But the differential effects of motion on the simulator performance does not transfer to the performance in the aircraft."
(Review of Koonce study)		Gundry, A. J.; (1975)	Dr. Gundry argued that the design of Koonce's experiment did not allow a conclusion on transfer of training to be made since there was no evidence that training occurred. In order to show training effects, a fourth group of subjects, equally as proficient as the other three groups but not trained in the simulator, would be required as a control for comparing performance in the aircraft.
Non-specific	General	Williges, Roscoe & Williges (1973)	"Research findings dealing with motion simulation are as yet inconclusive. Results may be divided into three categories: those that support the value of motion, those that suggest that the value of motion depends upon the transfer task, and those that suggest that the value of motion is merely a transient effect." An additional comment by the authors: "...the question of whether or not motion cues influence transfer at all is, as yet, unanswered."

TABLE 6. LITERATURE SURVEY RESULTS -- QUESTIONING THE EFFECTS OF MOTION CUEING (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Tracking	Roll & pitch Gat 2	Jacobs, Williges & Roscoe (1973)	<p>A study comparing various flight-director displays in a moving base simulator was replicated without motion. The results: pilot performance in azimuth steering on the eight displays (four compensatory and four pursuit) was better with simulator motion than without. These results confirm those of studies such as that by Matheny, Dougherty, and Willis (1963) that have shown simulator motion to facilitate manual control performance. The authors, however, state that as the simulator does not supply the motion feedback information through the same channels and in the same scale as the pilot has been trained to expect in the aircraft, important performance differences may occur. These differences may be subtle but they will affect the results of simulator experimentation. This is not to say that such experimentation cannot be generalized to the airborne situation but rather that considerable caution must be exercised in doing so. The authors identify problems concerning the task, the testing sequence, and the subject population aspects of the experimental design that could have contributed to minimization or distortion of differences among experimental conditions. (They seem reluctant to accept the results of their own study.) They add: "Attention to these details in future studies will, hopefully, lead to a more conclusive demonstration of the primary effects and major interactions."</p>

TABLE 7. LITERATURE REVIEW -- ALGORITHM PERTINENT COMMENTS

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
Engine failure	Yaw	Borah (1976)	Attitude and angular rate perceptions may be contradictory, and it is impossible in a three rotational degree-of-freedom simulation to duplicate both simultaneously. "It was determined that a three degree of freedom (rotational) system should probably remain faithful to the attitude perception even at the expense of incorrect angular rate of sensations."
Instrument	Yaw	Cooper (1966)	"Onset and very brief sustained 'g' lead to adequate representation for simulating engine failure, even for excursions programmed to be as low as 4 inches."
	Roll, pitch, yaw	Cutler (1966)	"In achieving motion perception (with visual help) linear position and velocity, and angular position, are not useful; changes (even transients) in linear acceleration and in angular velocity and acceleration are most useful."
V/STOL	Roll, pitch, heave	Davis & Beadsmore (1970)	"In fact we are not really satisfied that a motion system with more than the standard three degrees of freedom (roll, pitch and heave) is necessary for a military simulator."
Training		Gerathewohl (1969)	"Motion must be of high fidelity and not result in spurious motion."
R&D simula- tion	Roll, pitch, heave sway	Graham (1960)	"Northrop investigators, who have used both methods, favor scaling. Use of washout apparently leads to very poor phase relationships between acceleration, velocity and displacement cues. Northrop's experience has been that washout works well only when the simulation as a whole is unrealistic, when the simulation is realistic, the effect of washout is to confuse the test subject."

TABLE 7. LITERATURE REVIEW -- ALGORITHM PERTINENT COMMENTS (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
R&D simula- tion	Roll, pitch, yaw, heave, sway	Hayden (1970)	Considered the various types of algorithms in use and selected a wash- out technique as being "best." Also determines the acceleration, velocity and excursion requirements as a function of aircraft type and maneuver response.
Air-to- air gunnery		Klier & Gage (1970)	"...simulator motion need not be a faithful reproduction of real-life motion in order to promote essential motion cues."
Light helicopt- er tracking	Roll, pitch, yaw & heave	Matheny & Wilkerson (1966)	"The hypothesis is advanced that the rate of onset of acceleration provides a sufficient cue to the operator to assist him in closed loop tracking control, however, this hypothesis should be tested experi- mentally."
Formation 6 DOF flight, loops		Rust (1975)	The importance of lag time and the correlation of visual and motion cues was emphasized. The visual system lag was reported to 100 ms, the motion system lag was 100-233 ms plus an increasing function of pilot input frequency. According to CAPT Rust's observations, the results of these time discrepancies were overcontrol or pilot-induced oscillations, particularly in roll. An interesting observation was made when a pilot (who hadn't flown ASUPT before) was flying aero- batics such as a loop using motion. Typically, in the pullout, he overcontrolled roll trying to keep the wings level. However, when motion was turned off and he didn't get the delayed motion cue, the overcontrolling was decreased by about 50 percent.
R&D simula- tion	6 DOF	Spitzer & Rumsey (1966)	"For the particular case of the Boeing 737, a very good simulation can be achieved using a washout filter of $1/(S+0.5)$ squared with a maximum amplitude of 4 feet and a limiting velocity of at least 2 feet per second."

TABLE 7. LITERATURE REVIEW -- ALGORITHM PERTINENT COMMENTS (Contd)

TASK	PRIMARY STIMULUS	SOURCE	COMMENTS
Fly the SST at high Mach numbers	6 DOF	White, Vomaske, McNeill & Cooper (1963)	Accurate appraisal of the effects of large disturbances of the airplane requires simulator capabilities that reproduce translational as well as rotational motions.
VTOL/ Hover	Pitch	Oldfield (1966)	Appropriately responsive motion simulation was helpful, while introduction of a motion response lag of about 0.5 second produced performance worse than in fixed base, adverse pilot comment, and nausea in three pilots.
Instru- ment simulator training visual aircraft maneuvers	Roll, pitch	Koonce (1974)	"Sustained motion resulted in higher predictive validities than the no motion or washout-type motion systems; and there were no significant differences between these later two motion systems in the predictive validities of the individual maneuvers." "But the differential effects of motion on the simulator performance does not transfer to the performance in the aircraft."
Comparison of various display formats	Roll, pitch	Ince, Williges & Roscoe (1975)	Overall performance in the simulator under washout banking and sustained pitching motion were reliably better and more representative of actual flight performance than performance without motion cues. The selection of preferred display formats was more nearly that selected by in the aircraft selection than was the no motion selection.

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TABLE 7. LITERATURE REVIEW -- ALGORITHM PERTINENT COMMENTS (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
NA	Nonspecific	Parrish & Dieudonne (1973)	"The pulse responses of the three filters indicate better motion fidelity, in terms of magnitude of the rotational anomalous cue and duration of the specific force anomalous cue, with the adaptive filter and the digital controller. The amplitude and phase vs frequency plots show marked improvement for the adaptive filter over the linear filter, and for the digital controller over both the adaptive and linear filters. The time histories of the steady state responses of the three filters to sinusoidal inputs clearly demonstrate not only the improvement in amplitude and phase errors, but also demonstrate the fact that the anomalous specific force cues generated by the nonlinear filters are less than or equal to those generated by the linear filter, particularly at low frequency."
NA	6 DOF	Parrish & Martin (1975)	"The subjective results of this study reveal a significant difference between the nonlinear washout method and the linear washout method used. The pilots rated the nonlinear washout as highly preferable to the linear washout, and specifically objected to anomalous rotational rate cues in roll and yaw with the linear method."
NA	6 DOF	Sinacori (1973)	"...the relevant motion perceptions used in this motion simulation philosophy is reiterated below: 1. Provide good angular velocity recovery at frequencies between .5 rad/sec and the simulated vehicle's bandwidth. 2. Provide good specific force recovery at frequencies from zero to the simulated vehicle's bandwidth. 3. The gain of the above may be varied to suit the task and the simulator." Sinacori's algorithm is essentially that of Schmidt and Conrad with the coordinating circuit modified to a lead-lag type.
ILS approach 731 simulation	5 DOF heave not used	Parrish & Martin (1975)	There were no statistical differences in the system measures taken between the no motion and the linear motion algorithm. Pilots felt the linear motion increased the pilot workload in a realistic fashion and were critical of anomalous cues.

TABLE 7. LITERATURE REVIEW -- ALGORITHM PERTINENT COMMENTS (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
ILS CTOL 737	6 DOF	Parrish & Martin (1976)	"Objective and subjective data gathered in the process of comparing a linear and a nonlinear washout for motion simulators reveal that there is no difference in the pilot-performance measurements used during instrument-landing-system (ILS) approaches with a Boeing 737 conventional take-off and landing (CTOL) airplane between fixed-base linear-washout, and non linear-washout operations. However, the subjective opinions of the pilots reveal an important advance in motion-cue presentation. The advance is not in the increased cue available over a linear filter for the same amount of motion base travel but rather in the elimination of false rotational rate cues presented by linear filters."
Non- specific	6 DOF	Schmidt & Conrad (1970)	Linear washout algorithms are preferred, to match linear specific force and angular velocity.
Non- specific	Roll	Sinacori (1977)	Roll motion improves pilot performance particularly when task loading is increased. Tilt cue (gravitational reaction component) further improves pilot performance. Spurious appearing side force cues can give tendencies toward disorientation. Roll motion scaling has a significant effect on pilot performance. Wash-out has a minor effect on pilot roll tracking performance.

TABLE 7. LITERATURE REVIEW -- ALGORITHM PERTINENT COMMENTS (Contd)

<u>TASK</u>	<u>PRIMARY STIMULUS</u>	<u>SOURCE</u>	<u>COMMENTS</u>
			Roll wash-out can be used to suppress the tilt cue but "quick" wash-outs cause disorientation.
			Miscoordination of side force can be used to reduce sway travel requirements.

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Motion Sickness
(simulator sickness)

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EFFECTS OF MOTION

Stress

(physiological and psychological; fatigue)

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EFFECTS OF MOTION

Acceleration

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APPENDIX B

CHRONOLOGICAL LISTING

"Scientific history, like histories of other human activities, at times has a way of behaving much like a musical rondo; themes tend to come 'round and 'round again."

Frank A. Geldard
(The Human Senses, 1972, p. 386)

In reviewing this chronological listing, it appears that the above quotation may be applicable to the topic of motion in flight simulation. Many of the perennial questions concerning motion simulation are still around, and still not answered satisfactorily.

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RUGGLES, W.G. - ORIENTATOR
PATENT NO. 1,342,871
FILED APRIL 16, 1917 GRANTED JUNE 8, 1920

RUGGLES, W.G. - ORIENTATOR
PATENT NO. 1,393,456
FILED SEP. 9, 1918 GRANTED OCT. 11, 1921

GWINNETT, C.E. - AMUSEMENT DEVICE
PATENT NO. 1,789,680
FILED OCT. 1, 1928 GRANTED JAN. 20, 1931

BLOKLEY, C.P. - AERONAUTICAL INSTRUCTING DEVICE
PATENT NO. 1,865,828
FILED JULY 3, 1929 GRANTED JULY 5, 1932

RISCH, A. - AIR PILOT TRAINING DEVICE AND THE LIKE
PATENT NO. 1,791,655
FILED DEC. 5, 1929 GRANTED FEB. 10, 1931

CLUSTER, L.L. - AVIATION TRAINING MACHINE
PATENT NO. 2,063,231
FILED SEP. 15, 1930 GRANTED DEC. 8, 1936

HUFFMAN, W.E. - FLIGHT TRAINER
PATENT NO. 1,944,180
FILED NOV. 17, 1932 GRANTED JAN. 23, 1934

LINK, F.A. JR. - TRAINER FOR AVIATORS
PATENT NO. 2,099,857
FILED AUG. 14, 1936 GRANTED NOV. 23, 1937

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PATENT NO. 2,301,625
FILED AUG. 13, 1940 GRANTED NOV. 10, 1942

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HICKER, W.C. ET AL - PRE-FLIGHT REFLEX AND GUNNERY TRAINER
PATENT NO. 2,316,181
FILED SEP. 10, 1941 GRANTED APRIL 13, 1943

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PATENT NO. 2,306,429
FILED DEC. 23, 1941 GRANTED DEC. 29, 1942

GEISSE, J.H. - AVIATION GROUND TRAINING MACHINE
PATENT NO. 2,323,322
FILED MAY 22, 1942 GRANTED JULY 6, 1943

HUTTER, W.T. - PILOT TRAINER
PATENT NO. 2,409,938
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LINK, E.A. ET AL - AVIATION TRAINER
PATENT NO. 2,358,016
FILED SEP. 9, 1942 GRANTED SEP. 12, 1944

PLATNER, L.O. - TRAINING DEVICE
PATENT NO. 2,344,454
FILED DEC. 7, 1942 GRANTED MARCH 14, 1944

ST. JOHN, E. - APPARATUS FOR USE IN TEACHING AND TRAINING AVIATORS
PATENT NO. 2,369,418
FILED APRIL 24, 1943 GRANTED FEB. 13, 1945

MALLAN, H.C. - AIRCRAFT TRAINING APPARATUS
PATENT NO. 2,357,481
FILED JUNE 5, 1943 GRANTED SEP. 5, 1944

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PATENT NO. 2,439,168
FILED JULY 31, 1943 GRANTED APRIL 6, 1948

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PATENT NO. 2,528,516
FILED MARCH 23, 1945 GRANTED NOV. 7, 1950

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PATENT NO. 2,524,238
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APPENDIX C

ALPHABETICAL LISTING

All reports are listed in this section, alphabetically by author, with abstracts.

ADAMS, J.A., BRIGGS, G.E., FLEXMAN, R.E., MATHENY, W.G. AND SOUTHARD, J.F. UDBFTT AS A RESEARCH VEHICLE FOR THE STUDY OF FIDELITY OF SIMULATION. COLUMBUS, OHIO: THE LABORATORY OF AVIATION PSYCHOLOGY, OSL, FOR THE NAVAL TRAINING DEVICE CENTER, FORT WASHINGTON, NEW YORK, 1962.

* ABSTRACT *

THE PURPOSE OF THIS REPORT IS TO SUGGEST EXPERIMENTAL APPROACHES THAT COULD POINT THE WAY TO APPLICATIONS OF UDBFTT WHERE TWO OR MORE PILOTS WOULD BE TRAINED AT THE SAME TIME. WHILE FOUR WAYS TO DO THIS HAVE BEEN SUGGESTED, ONLY THREE ARE RELEVANT TO UDBFTT AND ARE RECOMMENDED FOR STUDY: REDUCING COMPUTATION RATE, SIMPLIFYING FLIGHT EQUATIONS, AND USING FEWER BREAK POINTS IN THE TABLED FUNCTIONS. THE EXISTING LITERATURE ON TRANSFER OF TRAINING CONTAINS ONLY SKETCHY INFORMATION ON HOW ATTENUATION OF UDBFTT SIMULATION IN THESE THREE WAYS WILL AFFECT ITS TRAINING VALUE, AND AN EXPERIMENTAL PROGRAM OF TRAINING RESEARCH ON UDBFTT ITSELF APPEARS NECESSARY. A SUCCESSFUL OUTCOME OF SUCH EXPERIMENTS MAY VERY WELL LEAD TO TWO, FOUR, OR EVEN MORE FLIGHT SIMULATORS ESSENTIALLY FOR THE PRICE OF ONE, AND THE SIGNIFICANCE OF THIS FOR THE ECONOMICS OF MILITARY FLIGHT TRAINING CANNOT BE UNDERESTIMATED.

ADAMS, J.A. AND CREAMER, L.R. PROPRIOCEPTION VARIABLES AS DETERMINERS OF ANTICIPATORY TIMING BEHAVIOR. HUMAN FACTORS, VOL. 4: 4 AUG 1962, 217-222.

* ABSTRACT *

ANTICIPATORY TIMING, WHERE THE HUMAN OPERATOR INITIATES AN ACCURATE RESPONSE BEFORE THE ACTUAL OCCURRENCE OF THE ENVIRONMENTAL EVENT, IS ONE OF THE MOST STRIKING AND LEAST STUDIED ASPECTS OF SKILLED MOTOR PERFORMANCE. AN EXPERIMENT WAS PERFORMED ON TEMPORAL AND CONTROL SYSTEM VARIABLES THAT COULD INFLUENCE THE TIMING OF RESPONSES IN A TRACKING TASK. VERIFICATION WAS SOUGHT FOR A PROPRIOCEPTIVE TRACE HYPOTHESIS THAT HOLDS THE TIME-VARYING PROPRIOCEPTIVE AFTER-EFFECTS OF MOVEMENTS TO BE THE INTERNAL TRACE THAT PERSISTS IN TIME AND CUES THE OCCURRENCE OF A FUTURE RESPONSE. NINETY-SIX SUBJECTS PARTICIPATED. A 2 X 2 X 2 RANDOMIZED FACTORIAL DESIGN USED TWO VALUES OF MOVEMENT AMPLITUDE, SPRING LOADING, AND SIGNAL DURATION AS A MEANS OF MANIPULATING PROPRIOCEPTIVE STIMULI AND THEIR TIME TRACE. RESULTS SUPPORTED THE HYPOTHESIS. SIGNAL DURATION AND SPRING LOADING OF THE CONTROL INDUCED SIGNIFICANT EFFECTS FOR THE NUMBER OF BENEFICIAL ANTICIPATIONS, BUT MOVEMENT AMPLITUDE HAD NO SIGNIFICANT EFFECT. IT WAS CONCLUDED THAT PROPRIOCEPTION HAS A ROLE IN RESPONSE TIMING, IN ADDITION TO ITS TRADITIONAL ONE OF INFORMATION FEEDBACK.

ADAMS, J.C. DYNAMIC REQUIREMENTS FOR SIMULATOR SERVO DRIVE MECHANISMS, AIAA PAPER NO. 70-355, 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE', CAPE CANAVERAL, FLORIDA, MARCH 16-18, 1970.

* ABSTRACT *

ANALYTICAL AND EXPERIMENTAL INVESTIGATIONS HAVE BEEN MADE OF THE MANUAL CONTROL PROBLEM IN WHICH THE DYNAMICS OF THE VEHICLE ARE REPRODUCED ON A COMPUTER, AND THE SYSTEM OUTPUTS ARE PRESENTED TO THE SUBJECT BY MEANS OF THE SIMULATOR DISPLAY MECHANISM. THE ANALYTICAL INVESTIGATION WAS MADE USING MODELS OF HUMAN RESPONSE. SYSTEM STABILITY FOR SINGLE-LOOP SYSTEMS WAS DETERMINED WITH A WIDE RANGE OF SIMULATOR DYNAMICS, AND IT IS SHOWN THAT THE SIMULATOR FREQUENCY SHOULD BE HIGHER THAN 20 RADIAN PER SECOND. FROM THE EXPERIMENTAL TESTS, AGREEMENT IS SHOWN REGARDING THE SIMULATOR DYNAMICS THAT CAUSE NEUTRAL SYSTEM STABILITY. SIMILAR STUDIES HAVE ALSO BEEN MADE IN A MULTILoop SYSTEM, THE LUNAR LANDING CONTROL TASK, WHERE THE EFFECT OF THE DYNAMIC RESPONSE OF THE OUTER-LOOP SIMULATOR DRIVE MECHANISM (TRANSLATION DRIVE MECHANISM) WAS STUDIED. THE AGREEMENT BETWEEN ANALYTIC AND EXPERIMENTAL RESULTS IS SHOWN.

ADAMS, J.C. AND BERGERON, H.P. MEASURED VARIATIONS IN THE TRANSFER FUNCTION OF A HUMAN PILOT. NASA LANGLEY RESEARCH CENTER, HAMPTON, VA. PRESENTED AT THE 'AIAA/ASD (AFSC) VEHICLE DESIGN AND PROPULSION MEETING', DAYTON, OHIO, NOVEMBER 4-6, 1963.

* ABSTRACT *

A METHOD FOR DETERMINING THE TRANSFER FUNCTION OF A HUMAN PILOT AS HE OPERATES ON A CLOSED-LOOP CONTROL SYSTEM HAS BEEN DEVISED AND USED IN SINGLE-AXIS COMPENSATORY TRACKING TASK AND TWO-AXIS TASKS BOTH WITH AND WITHOUT MOVEMENT. THE TRANSFER FUNCTIONS WERE THEN USED ANALYTICALLY TO OBTAIN CLOSED-LOOP CHARACTERISTICS.

ADAMS, J.C. AND BERGERON, H.P., MEASURED VARIATIONS IN THE TRANSFER FUNCTION OF A HUMAN PILOT. 'JOURNAL OF AIRCRAFT', VOL 1, #2, MARCH - APRIL 1964.

* ABSTRACT *

A METHOD FOR DETERMINING THE TRANSFER FUNCTION OF A HUMAN PILOT AS HE OPERATES ON A CLOSED-LOOP CONTROL SYSTEM HAS BEEN DEVISED AND USED IN SINGLE-AXIS COMPENSATORY TRACKING TASKS AND TWO-AXIS TASKS BOTH WITH AND WITHOUT COCKPIT MOVEMENT. THE TRANSFER FUNCTIONS WERE THEN USED ANALYTICALLY TO OBTAIN CLOSED-LOOP CHARACTERISTICS.

*ALSO PRESENTED AT THE AIAA/ASD (AFSC) VEHICLE DESIGN AND PROPULSION MEETING, DAYTON, OH, NOV 4-6, 1963.

ADAMS, J.S. 'SOME CONSIDERATIONS IN THE DESIGN AND USE OF DYNAMIC FLIGHT SIMULATORS'. AIR FORCE PERSONNEL AND TRAINING RESEARCH CENTER, LACKLAND AIR FORCE BASE, TEXAS. RESEARCH REPORT AFRTTC-TN-57-51 MARCH, 1957.

* ABSTRACT *

THE PURPOSE OF THIS REPORT IS TO SPECIFY A PHILOSOPHY FOR FLIGHT-SIMULATOR DESIGN AND UTILIZATION, PARTICULARLY IN REFERENCE TO CURRENT AND FUTURE MANNED AIR WEAPONS. IN WHOLE-TASK SIMULATORS AN EXPLICIT ATTEMPT IS MADE TO PROVIDE COMPREHENSIVE SIMULATION FOR MISSION TRAINING. IN PART-TASK SIMULATORS THE SIMULATION IS EXPLICITLY LIMITED TO A CRUCIAL, DIFFICULT PORTION OF THE TOTAL JOB. DEFINING PRINCIPLES ARE NEEDED TO GUIDE THE DESIGN AND USE OF BOTH TYPES OF SIMULATORS IN TRAINING AND PROFICIENCY MEASUREMENT.

CERTAIN PRESENT DAY, WHOLE-TASK AND PART-TASK SIMULATORS ARE EXAMINED IN RELATION TO STATED PROFICIENCY MEASUREMENT AND TRAINING CRITERIA. IN ADDITION, THE LITERATURE ON TRANSFER OF TRAINING IS SURVEYED AND RELATED TO FIDELITY-OF-SIMULATION.

THE CONCLUSIONS DRAWN WERE:

1. THE MAJOR SHORTCOMING OF WHOLE TASK SIMULATORS IS THAT THEY DO NOT SIMULATE ENOUGH OF THE AIRCREW JOB-COMPLEX.

2. AN ANALYSIS OF CERTAIN PART-TASK SIMULATORS NOW IN USE INDICATES THAT A PRINCIPLE PROBLEM IS HOW MUCH TO SIMULATE. SOME PRESENT DAY PART-TASK SIMULATORS SUCCESSFULLY ABSTRACT FROM THE WHOLE TASK, OTHERS RESULT IN ZERO OR NEGATIVE TRANSFER TO THE OPERATIONAL TASKS.

3. CERTAIN DIMENSIONS OF FLIGHT SIMULATORS CAN BE SYSTEMATICALLY DEGRADED FOR TRAINING PURPOSES WITHOUT REDUCING THE AMOUNT OF POSITIVE TRANSFER. WHENEVER AIRCREW JUDGEMENT OR ACTION IS BASED ON PRECISE VALUES, GREAT CARE SHOULD BE EXERCISED IN SIMULATING THESE QUALITIES.

4. CONTROL FEEL CAN DEViate FROM AIRCRAFT VALUES WITHOUT AFFECTING TRANSFER BUT SUCH VARIATIONS DISTURB THE MOMENTARY PERFORMANCE LEVEL OF THE CREW MEMBER BEING EVALUATED. CONSEQUENTLY, A FLIGHT SIMULATOR DESIGNED TO MAXIMIZE TRANSFER MAY NOT NECESSARILY BE SATISFACTORY FOR PROFICIENCY MEASUREMENT.

AGIN, L.O., MARCUM, S.G., DAUGHERTY, F.J., FERRELL, M.B. AND TRAGER, F.N. AIRSICKNESS AND RELATED PSYCHOSOMATIC COMPLAINTS. 'AIR SURGEON'S BULLETIN', 2:235, 1975.

* ABSTRACT *

AIRSICKNESS, A TYPE OF MOTION SICKNESS WHICH AFFLICTS SOME MEN WHEN THEY FLY, IS OF THREE TYPES: (1) AIRSICKNESS CAUSED BY APPREHENSION IN EARLY TRAINING; (2) CHRONIC AIRSICKNESS ATTRIBUTED TO HYPERSENSITIVITY OF ORGANS IN THE INTERNAL EAR; (3) CASES OCCURRING AFTER A PERIOD OF NORMAL FLYING SUCH AS THOSE CAUSED BY ILLNESS, CHANGE OF PLANE TYPE OR FLIGHT STATION OR A NEUROISIS ARISING FROM LOSS OF INTEREST IN FLYING.

THIS IS A RECORD OF AN EXPERIMENT CONDUCTED BECAUSE THE BASE FLIGHT SURGEON BECAME ACUTELY AWARE OF A RISING INCIDENCE OF AIRSICKNESS AMONG B-24 COMBAT CREWS WITH RESULTANT GROUNDING AND LOSS OF FLYING PERSONNEL.

THE RESULTS INDICATE THAT A NUMBER OF FACTORS CONTRIBUTE TO THE PROBLEM. PREDISPOSITIONAL FACTORS IN FAMILY AND PERSONAL HISTORY CONTRIBUTE TO MALADJUSTMENT AND THUS TO THE PSYCHOSOMATIC DISTURBANCES OF AIRSICKNESS. INTENSIVE SCHEDULES OF FLYING, GROUND SCHOOL AND OTHER TRAINING WHICH ON OCCASION MAKE FOR 14-15 HOURS PER DAY AGGRAVATE THE TENDENCY TOWARD AIRSICKNESS. FAILURE TO DEAL PROMPTLY WITH AIRSICKNESS AND RELATED SOMATIC COMPLAINTS IN GUNNERY SCHOOL ADDS TO THE COST IN MONEY, TIME AND MAN POWER OF TRAINING COMBAT CREWS.

WILHARRAH, R.C. LOW ALTITUDE, HIGH-SPEED HANDLING AND RIDING QUALITIES. 'ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT', NORTH ATLANTIC TREATY ORGANIZATION, PARIS, FRANCE, REPORT 443, APRIL 1963, 44 PP, AD 431 320

* ABSTRACT *

THE RESULTS OF A COMBINED FLIGHT AND GROUND BASED DYNAMIC FLIGHT SIMULATOR STUDY OF THE HANDLING AND RIDING QUALITIES PROBLEMS ASSOCIATED WITH LOW-ALTITUDE, HIGH-SPEED FLIGHT ARE PRESENTED IN THIS PAPER. WIDE VARIATIONS OF THE LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS, WHICH CAN BE CONSIDERED REPRESENTATIVE OF CURRENT AND FUTURE STRIKE AIRCRAFT, WERE PILOT EVALUATED. THE INFLUENCE OF THESE STABILITY AND CONTROL CHARACTERISTICS, AS WELL AS THE EFFECTS OF LOW ALTITUDE TURBULENCE ON THE PILOTS TERRAIN FOLLOWING PERFORMANCE, WERE MEASURED. THE RESULTS OF THIS COMPREHENSIVE INVESTIGATION WERE PRESENTED IN TERMS OF ISO-PERFORMANCE BOUNDARIES DEFINING THE DESIRED AND REQUIRED COMBINATIONS OF STABILITY AND CONTROL PARAMETERS FOR LOW-ALTITUDE, HIGH-SPEED FLIGHT. THESE ACCEPTANCE BOUNDARIES ARE SIGNIFICANTLY DIFFERENT FROM THE SYSTEM CHARACTERISTICS, WHICH TEND TO BECOME UNSTABLE WHEN

COUPLED WITH THE PILOTS' RESPONSE (I.E. PILOT INDUCED OSCILLATIONS), HAVE BEEN DEFINED.

ALHARRAH, R.C.
FLIGHT SIMULATION, PAST, PRESENT AND FUTURE.
AIAA SECOND ANNUAL MEETING AIAA PAPER 65-480,
SAN FRANCISCO, CA, JULY 26-29, 1965.

* ABSTRACT *

THIS PAPER PRESENTS AN OVERVIEW OF FLIGHT SIMULATION AS USED IN SUPPORT OF TODAY'S AEROSPACE RESEARCH AND DEVELOPMENT PROGRAMS. THE CURRENT PRACTICES IN APPLICATION OF SIMULATION TECHNOLOGY IN TERMS OF COMPUTER SUPPORT, VISUAL DISPLAY TECHNIQUES, AND NOTION PROVISIONS ARE INDICATED. PICTORIAL COVERAGE IS INCLUDED FOR A REPRESENTATIVE CROSS SECTION OF FLIGHT SIMULATION FACILITIES THROUGHOUT GERMANY, THE UNITED KINGDOM, AND THE UNITED STATES. (AUTHOR)

ALHARRAH, R.C. AND SCHULZE, R.P. AN INVESTIGATION OF LOW-ALTITUDE, HIGH SPEED FLYING AND RIDING QUALITIES OF AIRCRAFT. NORTH AMERICAN AVIATION, INC., COLUMBUS DIVISION, COLUMBUS, OHIO, REPORT NA62H-397, FEB. 1963.

* ABSTRACT *

THE RESULTS OF A COMBINED FLIGHT PROGRAM AND GROUND-BASED DYNAMIC FLIGHT SIMULATOR STUDY OF THE HANDLING AND RIDING QUALITIES PROBLEMS ASSOCIATED WITH LOW-ALTITUDE, HIGH-SPEED FLIGHT ARE PRESENTED. WIDE VARIATIONS OF LONGITUDINAL STABILITY AND CONTROL CHARACTERISTICS WERE PILOT-EVALUATED AND PILOT PERFORMANCE WAS MEASURED FOR A TERRAIN FOLLOWING TASK FLOWN AT VARYING LEVELS OF ATMOSPHERIC TURBULENCE. PILOT ISOPHONIC MAPPINGS OF LONGITUDINAL STATIC AND DYNAMIC STABILITY FOR VARIOUS CONTROL SYSTEMS ARE CHOSEN, WITH REGIONS EXHIBITING PILOT INDUCED OSCILLATION (PIO) TENDENCIES DENOTED. PILOT TOLERANCE TO GUST-INDUCED ACCELERATION IS ESTABLISHED ALONG WITH THE INFLUENCE OF STABILITY, CONTROL AND TURBULENCE ON PILOT PERFORMANCE. (AUTHOR)

A.C. AKISTER ET AL - IMPROVEMENTS IN OR RELATING TO GROUND-BASED FLIGHT SIMULATING APPARATUS
PATENT NO. 1,224,505 (GREAT BRITAIN)
FILED JAN 27, 1969 GRANTED MAR. 10, 1971

ALBERRY, W.E., GUM, D.R., HUNTER, E.D.
FUTURE TRENDS AND PLANS IN MOTION AND FORCE SIMULATION DEVELOP-
MENT IN THE AIR FORCE, USAF HUMAN RESOURCES LABORATORY, WRIGHT-
PATTERSON AFB, OHIO IN 'AIAA VISUAL AND MOTION SIMULATION CON-
FERENCE', DAYTON, OHIO, APRIL 26-28 1976

* ABSTRACT *

IN THIS PAPER THE AIR FORCE'S FUTURE TRENDS AND PLANS IN MOTION
AND FORCE SIMULATION DEVELOPMENT ARE PRESENTED. A THREE-FOLD
APPROACH TO THE PROBLEM OF PROVIDING ANSWERS TO SIMULATION
REQUIREMENTS FOR THE AIR FORCE NOW AND IN THE FUTURE IS
DISCUSSED. THE FIRST APPROACH IS TO TAKE A LOOK AT THE HUMAN
AND TO DETERMINE AND DESCRIBE HIS MOTION AND FORCE SENSORY
MECHANISMS. EARLIER WORK IN SENSORY MECHANISM MODELING IS
PRESENTED; A NEW EFFORT, BASED ON AN OPTIMAL PROCESSOR MODEL
FOR PERCEPTION AND CONTROL IS DISCUSSED. THE SECOND APPROACH,
AN ADVANCED DEVELOPMENT PROGRAM, WHICH INCLUDES THE DESIGN OF A
SECOND GENERATION G-CUEING SEAT DEVICE, IS SUMMARIZED. THE
THIRD APPROACH, EXPLORATORY DEVELOPMENT, IS OUTLINED AND THE
AIR FORCE'S ENGINEERING EXPERIMENTATION ON CURRENT G-SEAT,
MOTION SYSTEMS, AND COMPONENTS AS WELL AS JOINT AIR FORCE/NASA
MOTION STUDIES ARE PRESENTED.

ALBERRY, W.E., GUM, D.R. AND KRON, G.J.
MOTION AND FORCE CUEING REQUIREMENTS AND TECHNIQUES FOR AD-
VANCED TACTICAL AIRCRAFT SIMULATION, PRESENTED AT AGARD MEETING
ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS,
BELGIUM, 24-27 APRIL 1978.

* ABSTRACT *

THE APPROACH BEING PURSUED BY THE U.S. AIR FORCE TO ADVANCE MO-
TION AND FORCE CUEING TECHNOLOGY FOR TACTICAL AIR FLIGHT SIMULA-
TIONS IS TWOFOLD. THE FIRST PART INCLUDES EFFORTS DIRECTED
TOWARDS BUILDING A DATA BASE ON WHICH TO BASE MOTION
AND FORCE CUEING REQUIREMENTS. THE SECOND PART INCLUDES
EFFORTS TO IMPROVE THE PERFORMANCE OF EXISTING DEVICES THAT HAVE
BEEN SHOWN TO BE SOMEWHAT EFFECTIVE AND TO DEVELOP NEW DEVICES
AND TECHNIQUES AS INDICATED BY THE DATA BASE EFFORTS. THE DATA
BASE DEVELOPMENT INVOLVES LOOKING AT THE PILOT WHO RECEIVES MO-
TION AND FORCE CUES AND THE AIRCRAFT AND ENVIRONMENT WHICH
IMPART THE MOTION AND FORCE CUES. MODELS OF HUMAN MOTION AND
FORCE SENSORY MECHANISMS (VESTIBULAR, TACTILE, VISUAL, AND
NAVESTIBULAR PROPRIOCEPTIVE) DESCRIBING HOW MOTION IS PERCEIVED
HAVE BEEN DEVELOPED AND THE MOTION AND FORCE ENVIRONMENT FOR
TACTICAL AIRCRAFT PERFORMING VARIOUS MANEUVERS IS BEING CHARAC-
TERIZED. THE RESULTS OF THESE EFFORTS ARE BEING USED TO DEFINE
MOTION AND FORCE CUEING REQUIREMENTS AND CONCEPTS FOR NEW DEVICES
TO IMPART THE NECESSARY CUES. CUEING DEVICE DEVELOPMENT EFFORTS

INCLUDE THE DEVELOPMENT OF THE NEXT GENERATION G-CUING (G-SEAT, G-SLIT, AND BUFFET) SYSTEM WITH IMPROVED RESPONSE AND ONSET CUING CAPABILITY; TECHNIQUES FOR HYDROELECTRIC CONTROL OF VISUAL SIMULATION SYSTEM BRIGHTNESS AND FIELD-OF-VIEW AS A FUNCTION OF THE G-FORCE ENVIRONMENT AND PILOT PHYSICAL ACTION; AND DESIGNS FOR SYSTEMS SUCH AS ARM, THIGH, AND HEAD LOADING DEVICES TO PROVIDE FOR SIMULATION OF THE EXTREMELY HIGH-G FLIGHT ENVIRONMENT.

ALPERY, WILLIAM B., HUNTER, ERICK D. G-SEAT COMPONENT DEVELOPMENT. AFHRL-TR-78-18. ADVANCED SYSTEMS DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433, JUNE 1978.

* ABSTRACT *

AN EFFORT WAS CONDUCTED TO INVESTIGATE THE IMPROVED PERFORMANCE OF A CLOSED-LOOP G-SEAT SYSTEM. THE AIR FORCE AND NAVY ARE CURRENTLY USING G-SEATS IN SEVERAL TRAINING AND FIGHTER SIMULATORS. THESE DEVICES ARE ALL OPEN-LOOP SYSTEMS AND EXHIBIT EXCESSIVE TIME DELAYS. WHILE THESE SEATS EXHIBIT GOOD SUSTAINED CUING CAPABILITY, THEIR PERFORMANCE IS MARGINAL IN PRODUCING OVERALL ACCELERATION CUES. BECAUSE OF SLUGGISH RESPONSE CHARACTERISTICS, VIRTUALLY NONE OF THE SEATS CAN GIVE APPROPRIATE ACCELERATION ONSET CUES AND BE IN SYNCHRONIZATION WITH CURRENT VISUAL SYSTEMS. CONVENTIONAL G-SEAT COMPONENTS WERE OBTAINED AS WELL AS ADVANCED, POSITION FEEDBACK METAL BELLOWS, AND A CLOSED-LOOP PNEUMATIC CONTROL SYSTEM WAS DESIGNED AND DEVELOPED. THE OPEN- AND CLOSED-LOOP PERFORMANCE OF THIS SYSTEM WAS EVALUATED AND THE CONTRIBUTION OF EACH COMPONENT IN THE G-SEAT HARDWARE WAS ANALYZED. TRANSFER FUNCTIONS WERE DEVELOPED FOR THE PNEUMATIC CONTROL SYSTEM.

ALPERY, WILLIAM B., MCGLIRE, DANNY C. EMULATION OF AN ADVANCED G-SEAT ON THE ADVANCED SIMULATOR FOR PILOT TRAINING. AFHRL-TR-78-4. ADVANCED SYSTEMS DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433, APRIL 1978.

* ABSTRACT *

AN IN-HOUSE EFFORT WAS INITIATED TO INVESTIGATE SIMPLE G-SEAT HARDWARE CONFIGURATIONS FOR THE PURPOSE OF DEVELOPING A LOW-COST APPROACH TO G-CUING SIMULATION IN FLIGHT TRAINERS. THE G-SEAT IS A MOTION AND FORCE SIMULATION DEVICE WHICH REPLACES THE AIRCRAFT SEAT IN A FLYING TRAINING SIMULATOR; BY VIRTUE OF ITS GEOMETRY AND SOFTWARE DRIVE, IT IMPARTS TACTILE CUES TO THE SEATED PILOT WHICH ARE REPRESENTATIVE OF THE SEAT FORCES NORMALLY EXPERIENCED IN ACTUAL FLIGHT. THE AIR FORCE AND NAVY ARE PROCURING G-SEATS FOR BOTH TRAINING AND FIGHTER SIMULATORS. THESE G-SEATS ARE RESEARCH DEVICES, AND HAVE UP TO 32 ACTUATORS DISTRIBUTED IN THE

NAVTRAEQUIPCEN IH-298

SEAT PAN, BACKREST, AND LAP BELT. THESE SEATS CAN BE IMPROVED UPON WITH RESPECT TO SIMPLER GEOMETRY, FEWER ACTIVE COMPONENTS, AND MORE EFFECTIVE DRIVE ALGORITHMS. THIS REPORT DESCRIBES A RESEARCH EFFORT ON THE AIR FORCE'S ADVANCED SIMULATOR FOR PILOT TRAINING (ASFT).

ALPIN, N., LEET, J. R., AND MULLENBOF, P. A.
GROUND-BASED FLIGHT SIMULATION OF THE CH-47C HELICOPTER.
BOEING CO., VERTOL DIV., PHILADELPHIA PA
REPORT DR-2418-1, FOR USAA VLABS, FORT EUSTIS, VA.,
OCTOBER 1969 (AD-864 115).

* ABSTRACT *

A GROUND-BASED SIMULATION OF THE CH-47C TANDEM ROTOR HELICOPTER WAS CONSTRUCTED AND EVALUATED. THE MATHEMATICAL MODEL PROVIDED A FULLY COUPLED, LARGE-PERTURBATION REPRESENTATION OF THE AIRCRAFT WHICH WAS USED IN CONJUNCTION WITH A FIVE-DEGREE-OF-FREEDOM MOTION BASE AND A WIDE ANGLE POINT LIGHT SOURCE VISUAL DISPLAY. THE MATHEMATICAL MODEL WAS VALIDATED BY COMPARING ITS STATIC AND DYNAMIC CHARACTERISTICS WITH FLIGHT TEST DATA. A TEST PILOT FLEW THE SIMULATED AIRCRAFT TO DETERMINE THE DEGREE OF REALISM ACHIEVED AND TO EVALUATE THE ACCURACY WITH WHICH THE CH-47 WAS REPRESENTED. REPRESENTATIVE DATA AND PILOT COMMENTS ARE PRESENTED IN SUPPORT OF THE EVALUATION. (AUTHOR)

ALLSOP, W.
PERSONAL COMMUNICATION, COMMERCIAL SIMULATOR SYMPOSIUM.
LINK MEMO NO 476-66-19, R. L. SMITH TO R. E. FLEXMAN.
1966.

* ABSTRACT *

THE DUPLICATION OF A/C MOTIONS MAY OR MAY NOT BE THE BEST METHOD FOR TRAINING. WHAT IS CRITICAL IS MERELY THE TRANSFER OF WHATEVER IS LEARNED, NO MATTER WHAT THE STIMULUS SITUATION WAS IN THE SIMULATOR.

ALLSOP, WILLIAM J. AND CURNUTT, ROBERT A.
THE BOEING CO, SEATTLE, WASH
70-346 MOTION SIMULATOR FOR FLIGHT CREW TRAINING. AIAA CONF
MARCH 16-18 1970 (CAPE)

ABSTRACT NOT AVAILABLE

ANASTASI, ANNE (PSYCHOLOGICAL TESTING). SECOND EDITION, THE
MACMILLAN CO.: NEW YORK, 1961.

* ABSTRACT *

THIS BOOK PROVIDES A COMPREHENSIVE VIEW OF CURRENT PSYCHOLOGICAL
TESTS AND TESTING PROBLEMS. CHAPTER 21, 'OTHER TECHNIQUES FOR
PERSONALITY ASSESSMENT', DISCUSSES PERCEPTUAL, COGNITIVE, AND
EVALUATIVE TASKS INCLUDING TESTS WHICH MEASURE FIELD DEPENDENCE.
WITKIN'S ROD AND FRAME TEST (RFT) AND THE EMBEDDED-FIGURE TEST
(EFT) ARE DESCRIBED IN THIS CHAPTER.

ANDERSON, V.T. AND PHILLIPS, J.F. USAF PILOT PROFICIENCY: AN
ANALYSIS OF ACTUAL AND SIMULATED FLIGHT DATA. MASTER'S THESIS,
DEFENSE LOGISTICS STUDIES INFORMATION EXCHANGE, UNITED STATES
ARMY LOGISTICS MANAGEMENT CENTER, FORT LEE, VIRGINIA. REPORT
NO. SLSR 20-76H SEPTEMBER 1976.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DETERMINE WHETHER USAF PILOT
PROFICIENCY HAS BEEN REDUCED SINCE THE IMPLEMENTATION OF ENERGY
CONSERVATION MEASURES (1972). THESE CONSERVATION MEASURES
RESULTED IN REDUCED ACTUAL FLYING AND THE INCREASED USE OF
FLIGHT SIMULATORS. A CENSUS OF TOTAL FLIGHT HOURS, AIRCRAFT
ACCIDENTS, AND SIMULATOR USAGE DATA WAS ANALYZED FOR A DEFINED
POPULATION OF PILOTS USING DIRECT COMPARISON, ANALYSIS OF
VARIANCE AND REGRESSION ANALYSIS TECHNIQUES. PILOT
IMPROFICIENCY (INVERSE OF PROFICIENCY) WAS DEFINED AS THE
AVERAGE COST PER AIRCRAFT ACCIDENT PER GIVEN PERIOD OF TIME.
THIS COST WAS USED TO QUANTIFY PILOT PROFICIENCY AND A
PREDICTION MODEL WAS FORMULATED TO DETERMINE ITS LEVEL WHEN
GIVEN FLIGHT AND SIMULATOR HOUR VARIABLES. OTHER VARIABLES,
SUCH AS PHASE OF FLIGHT, AIRCRAFT TYPE, PILOT-IN-COMMAND,
INSTRUCTOR PILOT TIME AND MAJOR COMMAND ASSIGNMENT WERE
EXAMINED IN THE TESTS OF THE RESEARCH HYPOTHESES. THE
CONCLUSIONS GIVEN THE DATA OF THE STUDY ARE: (1) THERE HAS
BEEN A DECREASE IN TOTAL FLYING PROFICIENCY, (2) THE DECREASE
IN PROFICIENCY CAN BE ATTRIBUTED TO REDUCTIONS IN ACTUAL FLIGHT
HOURS AND TO INCREASES IN THE USE OF FLIGHT SIMULATORS AS A
SUBSTITUTE FOR ACTUAL FLIGHT.

ANONYMOUS
REPORT ON THE USE OF THE DYNAMIC SIMULATOR.
(THE FRANKLIN INSTITUTE), LABORATORIES FOR RESEARCH AND
DEVELOPMENT
INTERIM REPORT I-2169-2, JUL 1952.

* ABSTRACT *

A VERY BRIEF AND UNPRETENTIOUS EXPERIMENTAL PROGRAM WAS CARRIED OUT USING THE DYNAMIC AIRCRAFT SIMULATOR, WHICH IS DESCRIBED IN FRANKLIN INSTITUTE REPORT F-2169, 'F-80A FLIGHT SIMULATOR' (DEILY ET AL., 1952). THE PURPOSE OF THIS EXPERIMENT WAS TO, FIRSTLY, DETERMINE THE VERBAL REACTIONS OF JET PILOTS TO THE ADEQUACY OF FLIGHT SIMULATION PRESENTED BY THE DYNAMIC SIMULATOR, AND SECONDLY, TO DETERMINE WHETHER IT WOULD BE FEASIBLE TO SYNTHESIZE A SIMPLE LINEAR TRANSFER FUNCTION DESCRIBING THE PILOT BY MEANS OF THE RESPONSE TO STEP INPUTS.

AN IMPRESSIVE 'PROOF' OF THE PILOTS' RELIABILITY IN ASSESSING THE FEEL OF THE SIMULATOR WAS DEMONSTRATED DURING THIS STUDY. A CHECK-UP ON THE COMPUTING CIRCUITRY OF THE SIMULATOR REVEALED THAT THE ORIGINAL VOLTAGE GRADIENT FOR ELEVATOR AND AZIMUTH HAD BEEN INCORRECT, AND THAT THE CHANGES SUGGESTED BY THE PILOTS RESULTED IN COMPENSATING FOR THIS ERROR WELL WITHIN THE LIMITS OF ENGINEERING ACCURACY.

ANONYMOUS
BELL HELICOPTER CORPORATION. RESULTS OF ENGINEERING TEST MADE ON THE FRANKLIN INSTITUTE DYNAMIC FLIGHT SIMULATOR. FORT WORTH, TEXAS, REPORT NO. D228-370-001, APRIL 1960, 48 PP. AD236 660
L65-1125

* ABSTRACT *

THE PURPOSE OF THESE TESTS WAS TO DETERMINE VELOCITY LIMITS, ACCELERATION LIMITS, MAGNITUDE AND FREQUENCY OF UNWANTED SIGNALS. PARTICULAR ATTENTION WAS GIVEN TO LOWER FREQUENCY, LARGE EXCURSION SIGNALS PRESENTED TO THE PLATFORM BY THE COMPUTER DURING THE SIMULATED FLIGHT. IT IS FELT THAT SIGNALS SUCH AS THESE ARE MORE REPRESENTATIVE OF THE ACTUAL MOTION OF THE HELICOPTER. CONCLUSIONS WERE THAT THE EXISTING DISTANCE AVAILABLE FOR ACCELERATION IS VERY NEAR OPTIMUM IN MOST CHANNELS. MOST OF THE NOISE NOTED HAD A DEFINITE FREQUENCY COMPONENT OF 2 CPS., THE PLATFORM NATURAL FREQUENCY IN MOST CHANNELS. IN MOST CASES LARGER SERVO VALUES WILL IMPROVE MAXIMUM VELOCITIES AND ACCELERATIONS OBTAINABLE, AS THE LARGEST PERCENTAGE OF THE HYDRAULIC PRESSURE DROP IS PRODUCED BY THE SERVO VALVE, WITH VERY LITTLE PRESSURE REMAINING TO ACCELERATE THE LOAD. MANY MODIFICATIONS WERE MADE TO IMPROVE THE PERFORMANCE OF THE PLATFORM DURING THE TEST. THE RESULTS SHOWN IN THIS REPORT REPRESENT THE OPTIMUM OBTAINED FROM THESE MODIFICATIONS.

ANONYMOUS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION GUIDE FOR PLANNING INVESTIGATIONS IN THE AMES PILOTED FLIGHT SIMULATORS. AMES RESEARCH CENTER, MAY 1962.

* ABSTRACT *

THIS GUIDE PROVIDES INFORMATION TO AID IN THE PLANNING OF RESEARCH USING THE AMES PILOTED FLIGHT SIMULATORS. IT CONTAINS MUCH DESCRIPTIVE MATERIAL ON THE MANY GROUND-BASED MOTION SIMULATORS AVAILABLE AT AMES RESEARCH CENTER AT THE TIME OF THE REPORT.

ANONYMOUS

RPT. NO. AMRL-TCR-63-25. SYMPOSIUM ON MOTION SICKNESS WITH SPECIAL REFERENCE TO WEIGHTLESSNESS. FINAL REPORT, JUN 63. AEROSPACE MEDICAL DIVISION, 6570TH AEROSPACE MEDICAL RESEARCH LABORATORIES, WRIGHT-PATTERSON AFB, OHIO

* ABSTRACT *

THIS REPORT COMPILES THE PAPERS PREPARED FOR THE SYMPOSIUM ON MOTION SICKNESS DURING A WEIGHTLESS STATE, HELD AT THE BEHAVIORAL SCIENCES LABORATORY, AEROSPACE MEDICAL LABORATORY, WRIGHT-PATTERSON AFB IN MARCH 1960. MOTION SICKNESS IS DEFINED, ITS ETIOLOGY IS DISCUSSED, AND PROPOSALS FOR PROPHYLAXIS AND TREATMENT ARE MADE.

IT CONTAINS A PANEL DISCUSSION AMONG THE PRINCIPAL CONTRIBUTORS OF THE SYMPOSIUM, A THEORETICAL STUDY AND TWO PAPERS DEALING WITH PERSONAL EXPERIENCES IN WEIGHTLESSNESS. THE HIGH INCIDENCE OF NAUSEA OCCURRING IN THE ZERO-G FLIGHTS WAS SUSPECTED TO BE LARGELY DUE TO THE EXCESSIVE ACCELERATIONS OCCURRING IN THE PRE- AND POST-ZERO-G PERIODS ACCOMPANYING THESE FLIGHTS. EVIDENCE TO DATE INDICATED THAT WEIGHTLESSNESS BY ITSELF WAS NOT NAUSEATING, HOWEVER RAPID HEAD MOVEMENTS IN THE ENVIRONMENT COULD RAPIDLY PRODUCE DISTURBING INFLUENCES.

ANONYMOUS

GENERAL PRECISION SYSTEMS, LTD. 1G SENSITIVE SEAT SYSTEM FOR FLIGHT SIMULATORS. REPORT SD/521/TD, ISSUE 1, AYLESBURY, BUCKS. SEPT., 1965.

NO ABSTRACT AVAILABLE AT TIME OF PUBLICATION

ANONYMOUS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, SIMULATION SCIENCES DIVISION, 'SIMULATOR FACILITIES DESCRIPTION SHEETS', (COVER LETTER FLE:243-2) AMES RESEARCH CENTER, MOFFETT FIELD, CA, APRIL 1970.

* ABSTRACT *

DESCRIPTION SHEETS WITH BRIEF OUTLINES OF FEATURES, PERFORMANCE SPECIFICATIONS AND LIMITATIONS OF NASA FLIGHT SIMULATORS.

ANONYMOUS

LINK DIVISION/SINGER COMPANY, BINGHAMTON, NEW YORK. FUTURE UNDERGRADUATE PILOT TRAINING (UPT) SYSTEM STUDY, PHASE II. SUMMARY REPORT. REPORT NO. LR 23918-2 SEPTEMBER 1970.

* ABSTRACT *

SIX REPORTS ARE INCLUDED IN THIS VOLUME. THESE REPORTS DOCUMENT RESEARCH CONDUCTED TO PROVIDE AN ASSESSMENT OF SIMULATION REQUIREMENTS AND TECHNOLOGY REQUIRED TO AID IN SELECTING CANDIDATE SYSTEMS FOR UPT 7590. THE APPROACH TO EACH STUDY WAS TO: RESEARCH THE LITERATURE AND SUMMARIZE CURRENT STATE OF THE ART TECHNOLOGY; PROJECT STATE OF THE ART IMPROVEMENTS TO THE 1975 - 1990 TIME FRAME; AND RECOMMEND CONCEPTS, SYSTEMS OR DEVICES FOR CONSIDERATION IN FUTURE UPT CANDIDATE SYSTEMS.

ANON. DYNAMIC MANNED VEHICLE SIMULATOR. (AIRCRAFT ENGINEERING), JANUARY 1972

* ABSTRACT *

THE SYSTEMS DIVISION OF THE BRITISH AIRCRAFT CORP. AT WEYBRIDGE HAS BUILT A SIX DEGREES OF FREEDOM MOTION SIMULATOR WITH A HIGH-INTENSITY POINT SOURCE LAMP VISUAL SYSTEM. THE VISUAL SYSTEM PROVIDES A FIELD OF VIEW OF 180 DEGREES Laterally AND 120 DEGREES VERTICALLY, WITH CORRECT PERSPECTIVE VIEW OF THE SCENE MODELLED ON THE TRANSPARENCY.

THE STANDARD CAPSULE SUITABLE FOR A WIDE RANGE OF WORK FEATURES A MEDIUM SIZE AIRCRAFT COCKPIT WITH SIDE-BY-SIDE SEATING FOR A CREW OF TWO, A VARIABLE INSTRUMENT LAYOUT AND DUAL CONTROL COLUMNS WITH ADJUSTABLE FEEL CHARACTERISTICS. ANY TYPE OF CAPSULE CAN BE FITTED TO THE UNIVERSAL MOUNT WITHIN THE SIZE AND LOAD RESTRICTIONS. THE SIZE LIMITATIONS ARE NOT RIGID AND AMPLE ROOM IS AVAILABLE FOR A REPRESENTATIVE TWO SEAT CIVIL AIRCRAFT COCKPIT OR A SECTION OF A SUBMARINE CONTROL ROOM. AT THE TIME OF THIS WRITING, THE DMVS FACILITY HAD THREE SEPARATE COCKPITS: A TYPICAL SINGLE-SEAT FIGHTER, A TYPICAL HELICOPTER ADAPTABLE TO SIMULATE A HOVERCRAFT OR FAST PATROL BOAT AND A TYPICAL TWO-PILOT 2/4 ENGINE AIRLINER, WITH EMPHASIS ON STOL AND VTOL CHARACTERISTICS.

ANONYMOUS

ARMY TRAINING DEVICE AGENCY.

FIVE-YEAR FLIGHT TRAINING SIMULATION DEVELOPMENT AND MANAGEMENT PLAN.

FISCAL YEARS 1976-1980.

REPORT ATDA-TR-75-0001, AD AC18-027, ORLANDO FL, 1975.

* ABSTRACT *

THIS REPORT PRESENTS THE US ARMY AVIATION FLIGHT TRAINING SIMULATION DEVELOPMENT AND MANAGEMENT PLAN FOR FISCAL YEARS 76 THRU 80. THE PLAN WAS DEVELOPED BY STAFF MEMBERS OF THE US ARMY TRAINING DEVICE AGENCY IN COORDINATION WITH TRAINING MANAGERS OF THE TRAINING AND DOCTRINE COMMAND AND HARDWARE DEVELOPERS OF THE ARMY MATERIEL COMMAND.

THE REPORT DESCRIBES RESEARCH AND DEVELOPMENT EFFORTS FOR THE 1976-1980 PLANNING PERIOD. THESE INCLUDE EXPLORATORY (6.2), ADVANCED (6.3), AND ENGINEERING (6.4) DEVELOPMENT EFFORTS. ALSO, PLANNING AND MANAGEMENT CONCEPTS FOR FACILITIES, MAINTENANCE AND SUPPORT, AND TRAINING SIMULATOR VALIDATION, ASSESSMENT, AND CERTIFICATION ARE DISCUSSED.

PART-TASK AND COCKPIT PROCEDURES TRAINERS ARE DESCRIBED AND THE BENEFITS DERIVED FROM THEIR UTILIZATION ARE DISCUSSED. ALSO PRESENTED ARE THE STATE-OF-THE-ART OF COMPUTATIONAL TECHNOLOGY RELEVANT TO ARMY AVIATION TRAINING MISSIONS, AN OVERVIEW OF ONGOING AND PROJECTED DOD AND NASA RESEARCH AND DEVELOPMENT RELEVANT TO FLIGHT TRAINING SIMULATORS, AND AN OVERVIEW OF FLIGHT SIMULATOR VISUAL TECHNOLOGY.

ANONYMOUS

EXPERIMENT COMPARING SIX DEGREES OF FREEDOM (DOF) MOTION BASE AND G SEAT/SUIT COMBINATIONS ON THE SIMULATOR FOR AIR-TO-AIR COMBAT (SAAC). ENCLOSURE TO LETTER 90:JLD 1500 SER:53, 13 FEB 1975, FROM COMMANDER FIGHTER WING ONE, NAS, OCEANA, VIRGINIA BEACH, VA.

* ABSTRACT *

THIS EXPERIMENT WAS CONDUCTED 13 NOV 1974 TO DETERMINE WHAT EFFECT THE SIX DOF MOTION BASE AND G SEAT/SUIT HAVE ON A PILOT'S ABILITY TO CONTROL THE SAAC. MEASUREMENTS OF G FORCE, PITCH RATE AND AILERON DEFLECTION WERE TAKEN WHILE FLYING IDENTICAL MANEUVERS UNDER VARYING CONDITIONS OF MOTION SIMULATION. THE FULL FIELD OF VIEW VISUAL SIMULATION WAS IN USE AT ALL TIMES WITH THREE VARIATIONS OF MOTION SIMULATION: SIX DOF MOTION BASE ONLY; G SEAT/SUIT ONLY; AND, SIX DOF MOTION BASE PLUS G SEAT/SUIT. THE TASK WAS TO FLY A LEFT TURN AT 3000 FT. ABOVE GROUND LEVEL, AT 500 KNOTS, IN FULL AFTERBURNER, AND WITH THE PILOT LOOKING BACK TO THE LEFT AND NEVER AT THE INSTRUMENTS. TWO TURNS FOR EACH CONDITION WERE REQUIRED: ONE AT AIRFRAME

DIFFERENT ANSET, AND ONE AT SOME PITCH RATE EASILY IDENTIFIABLE BY THE PILOT.

NO SIGNIFICANT DIFFERENCES IN THE QUALITY OF CONTROL OUTPUT FOR THE THREE DIFFERENT CONDITIONS OF MOTION WERE FOUND.

PILOT OBSERVATIONS WERE THAT THE G SEAT PROVIDED GOOD FIDELITY TO FOUR G'S, BUT IT SEEMED TO PEAK AT THAT LOAD AND NOT PROVIDE ANY ADDITIONAL CUEING AT GREATER THAN FOUR G'S. AT THESE HIGHER G LOADS, THE G SUIT PROVIDED NOTICEABLE CUEING FOR 1/2 TO ONE G CHANGES UP TO FIVE G'S AND WAS UNUSEABLE BEYOND THAT POINT. THERE WAS NO RELIABLE G INDICATION IN EXCESS OF SIX G'S. WHEN RELAXING G THE SEAT DID NOT PROVIDE ANY NOTICEABLE CUE UNTIL 1.5 TO TWO G'S WAS REACHED. AT THAT POINT, THE PRESSURE DECREASE WAS NOTICEABLE. WHEN GOING FROM A HIGH G TO LOW G AND BACK TO HIGH (WITH G SEAT ONLY OPERATING) THERE WERE MOMENTS WHEN A SORT OF REVERSE CUEING WAS DELIVERED BY THE G SEAT. THIS SENSATION WAS NOT FELT WHEN THE G SUIT WAS USED WITH THE G SEAT. THE USE OF SIX DEGREES OF MOTION CAUSED A NOTICEABLE FORE AND AFT SENSATION OF MOVEMENT. THIS WAS NOT THE RESULT OF FLIGHT ACCELERATION AND SEEMED TO BE SPURIOUS IN NATURE. IT WAS LESS NOTICEABLE WHEN THE G SEAT AND G SUIT WERE IN USE. THE G SEAT PROVIDED VERY GOOD SIMULATION OF AFTERBURNER ACCELERATION AND UNLOADING FROM POSITIVE TO ZERO G.

ANAN.
ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT,
PARIS FRANCE.
APPROACH AND LANDING SIMULATION.
REPORT NO. AGARD-R-632., OCTOBER 1975 AD A018-179.

* ABSTRACT *

THIS REPORT PRIMARILY DISCUSSES NON-HARDWARE ASPECTS OF APPROACH AND LANDING SIMULATION. MODELS ARE PRESENTED FOR EXTERNAL DISTURBANCES, INCLUDING WIND SHEAR, TURBULENCE, ILTNOISE AND RUNWAY ROUGHNESS. MAJOR CONSTRAINTS ON THE FIDELITY OF VISUAL AND MOTION CUES THAT CAN OCCUR IN GROUND-BASED SIMULATORS ARE SUMMARIZED, AND EXPERIENCE REGARDING OVERALL SIMULATION DEVELOPMENT AND VALIDATION INCLUDING THE EFFECTS OF THE PILOTS LEARNING REQUIREMENTS IN SIMULATION PROGRAMS ARE REVIEWED.

ANONYMOUS
FLIGHT SIMULATORS - HEARING BEFORE THE SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT OF THE COMMITTEE ON ARMED SERVICES, U.S. SENATE, 94TH CONGRESS, SECOND SESSION, MAY 13, 1976. U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 1976.

* ABSTRACT *

A PRESENTATION OF FLIGHT SIMULATORS BY THE DEPARTMENT OF DEFENSE TO THE RESEARCH AND DEVELOPMENT SUBCOMMITTEE.

THE DIFFERENCE OF OPINION AMONG THE SERVICES AS TO WHETHER MOTION IS REQUIRED FOR FLIGHT TRAINING WAS DISCUSSED (PAGES 35-36). THE AIR FORCE DISCUSSED THE CONTRIBUTIONS OF MOTION TO SIMULATION SYSTEMS INCORPORATING NARROW FIELDS OF VIEW BUT ALSO STATED THAT THERE WAS EVIDENCE TO INDICATE THAT IN VISUAL SYSTEMS WITH GOOD PERIPHERAL CUES (WIDE ANGLE), PERHAPS MOTION DOES NOT CONTRIBUTE AS MUCH TO PERFORMANCE. IT WAS STATED THAT '...WORK DONE BY NASA CLEARLY SHOWS THAT MOTION, WHEN IT EXISTS IN A SIMULATOR, ALLOWS YOU TO FLY AND PERFORM BETTER WITH REDUCED FIDELITY...'

SOME OF THE ASUPT CAPABILITIES AND LIMITATIONS WERE DISCUSSED BY THE AIR FORCE. IT WAS STATED THAT, 'WE HAVE NOT YET FOUND A WAY TO SIMULATE THE ONSET CUES ACCURATELY ENOUGH WITH THIS DEVICE.' (P.43).

M. ARONSON - ASSAULT BOAT COXSWAIN TRAINER
PATENT NO. 3,486,242
FILED MAY 29, 1967 GRANTED DEC. 30, 1969

NO ABSTRACT

ASHKENAS, I.L., EX, H.R. AND MCRUER, D.T. 'PILOT-INDUCED OSCILLATIONS: THEIR CAUSE AND ANALYSIS'. NORAIR REPORT NORA-64-143, JUNE 1964.

* ABSTRACT *

SYSTEMS ANALYSIS TECHNIQUES ARE APPLIED TO THE PROBLEM OF PILOT-INDUCED AIRCRAFT OSCILLATIONS (PIO). MATHEMATICAL MODELS USED FOR THE PILOT PRIOR TO AND DURING PIO, AS WELL AS THE USE OF VARIOUS PILOT AND SUBSYSTEM DESCRIBING FUNCTIONS, ARE REVIEWED. SEVERAL EXAMPLES OF PIO CAUSES, ANALYSES, AND CURES ARE GIVEN, INCLUDING LINEAR AND NONLINEAR LONGITUDINAL PIO. THE CLOSED-LOOP DESCRIBING FUNCTION FOR A RATE-LIMITED POSITION SERV0 IS DERIVED IN THE APPENDIX.

ASHKENAS, I.L. AND MCRUER, D.T. A THEORY OF HANDLING QUALITIES DERIVED FROM PILOT VEHICLE CONSIDERATIONS. 'INSTITUTE OF THE AEROSPACE SCIENCES' IAS PAPER 62-39, JAN 1962.

* ABSTRACT *

STABILITY AND CONTROL REQUIREMENTS FOR MANNED VEHICLES HAVE BEEN BASED PRIMARILY UPON EXTENSIVE FLIGHT TEST EXPERIENCE LEAVENED WITH ENGINEERING JUDGMENT. CONSEQUENTLY, HANDLING QUALITIES REQUIREMENTS HAVE TENDED TO BE DIVERSE AND APPARENTLY UNRELATED SPECIFICS WHICH WERE NOT READILY DERIVABLE FROM AN ANALYTICAL THEORY. MANY DYNAMIC HANDLING QUALITIES HAVE BEEN TIED CONCEPTUALLY TO OPERATION OF THE PILOT-VEHICLE COMBINATION AS A CLOSED-LOOP SYSTEM, BUT THESE CONCEPTUAL TIES HAVE BEEN DIFFICULT TO TRANSLATE INTO THE PRACTICAL SPECIFICS REQUIRED BY THE DESIGNER.

RECENTLY, HOWEVER, THE APPLICATION OF SERVOANALYSIS METHODS TO PILOT-AIRCRAFT SYSTEM STUDIES HAS REACHED A STATE WHICH ALLOWS THE EXPLORATION OF MANY DYNAMIC HANDLING QUALITIES PROBLEM AREAS IN TERMS OF SIMPLE, ANALYTICAL, CLOSED-LOOP MODELS. IN THIS PAPER, THE ELEMENTS OF THE THEORY ARE PRESENTED AND APPLIED TO MAKE PREDICTIONS ABOUT HANDLING QUALITIES SITUATIONS WHICH HAVE OCCURRED IN PAST PRACTICE, AND WHICH MAY OCCUR FOR SOME FUTURE CONDITIONS. THE PAST PRACTICE PREDICTIONS ARE THEN SHOWN TO CORRELATE WELL WITH EXISTING FLIGHT AND SIMULATOR DATA, AND THE FUTURE CONDITIONS PREDICTIONS ARE COMPARED WITH VALIDATING TESTS PERFORMED IN SIMULATORS. FINALLY, THE CONSEQUENCES OF THE THEORY, IN TERMS OF SIGNIFICANT HANDLING QUALITIES PARAMETERS, ARE SUMMARIZED, AND PROBABLE RESTRICTIONS ARE NOTED. FOR FUTURE VEHICLES, WHERE OPERATIONAL EXPERIENCE WILL BE QUITE LIMITED, THE PARAMETER SUMMARY AND ASSOCIATED CRITERIA CAN PROVIDE AN INTERIM BASIS FOR DESIGN AND A GUIDE TO FUTURE TESTING.

(AUTHORS)

ASHWORTH, B.R. AND KAHLBAUM, W.M. JR. DESCRIPTION AND PERFORMANCE OF THE LANGLEY DIFFERENTIAL MANEUVERING SIMULATOR. NASA-LANGLEY, TECHNICAL NOTE TN D-7304, JUNE 1973.

* ABSTRACT *

THE LANGLEY DIFFERENTIAL MANEUVERING SIMULATOR (DMS) PROVIDES A REALISTIC MEANS OF SIMULATING TWO AIRCRAFT OR SPACECRAFT OPERATING IN A DIFFERENTIAL MODE. THE SYSTEM CONSISTS OF TWO IDENTICAL FIXED-BASE COCKPITS AND PROJECTION SYSTEMS, EACH HOUSED IN A 12.2-M-DIAMETER (40-FT) SPHERICAL PROJECTION SCREEN. EACH PROJECTION SYSTEM CONSISTS OF A SKY-EARTH PROJECTOR TO PROVIDE A HORIZON REFERENCE AND A SYSTEM FOR TARGET-IMAGE GENERATION AND PROJECTION. THE PROJECTORS AND IMAGE GENERATORS ARE GIMBALED TO ALLOW VISUAL SIMULATION WITH COMPLETELY UNRESTRICTED FREEDOM OF MOTION. THE COCKPIT CONTAINS TYPICAL INSTRUMENTATION, A G-SUIT, A PROGRAMMABLE BUFFET MECHANISM, AND PROGRAMMABLE CONTROL FORCES. THE SYSTEM WAS DESIGNED TO ACCOMMODATE SIMULATION OF A WIDE RANGE OF AIRCRAFT PERFORMANCE.

THIS REPORT GIVES A DETAILED DESCRIPTION OF THE HARDWARE AND ALSO DESCRIBES TESTS WHICH WERE PERFORMED TO VERIFY THAT THE SYSTEM COULD PROVIDE THE REQUIRED SIMULATED AIRCRAFT MOTIONS. THE MATHEMATICAL MODEL WHICH CONVERTS COMPUTED AIRCRAFT MOTIONS INTO THE REQUIRED MOTIONS OF THE VARIOUS PROJECTOR GIMBALS IS DESCRIBED.

ASHWORTH, B.R., MCKISSICK, B.T. AND MARTIN, D.J. JR. OBJECTIVE AND SUBJECTIVE EVALUATION OF THE EFFECTS OF A G-SEAT ON PILOT/SIMULATOR PERFORMANCE DURING A TRACKING TASK. PAPER TO BE PRESENTED AT THE '10TH NTEC/INDUSTRY CONFERENCE', ORLANDO, FLORIDA NOVEMBER 15-17, 1977

* ABSTRACT *

A SEAT CUSHION TO PROVIDE ACCELERATION CUES FOR AIRCRAFT SIMULATOR PILOTS HAS BEEN BUILT, PERFORMANCE TESTED, AND EVALUATED IN NASA LANGLEY'S DIFFERENTIAL MANEUVERING SIMULATOR. THE FOUR CELL SEAT, USING A THIN AIR CUSHION WITH HIGHLY RESPONSIVE PRESSURE CONTROL, ATTEMPTS TO REPRODUCE THE SAME EVENTS WHICH OCCUR IN AN AIRCRAFT SEAT UNDER ACCELERATION LOADING. THE PRESSURE CONTROLLER PROVIDES SEAT CUSHION RESPONSES WHICH ARE CONSIDERED ADEQUATE FOR CURRENT HIGH PERFORMANCE AIRCRAFT SIMULATIONS.

AN EXPERIMENT WAS DESIGNED TO EVALUATE THE EFFECT OF THE G-SEAT ON PILOT/SIMULATOR PERFORMANCE. THE STATISTICAL ANALYSIS OF DATA INDICATES THAT THE PILOT GETS INFORMATION FROM THE SEAT WHICH ALLOWS MORE PRECISE CONTROL OF THE SIMULATED AIRCRAFT. PILOT SUBJECTIVE DATA SUPPORT THE CONCLUSIONS OF THE STATISTICAL ANALYSIS.

BILLY R. ASHWORTH AND BURNELL T. MCKISSICK, NASA LANGLEY RESEARCH CENTER (LRC), DENNIS J. MARTIN, JR., SPERRY SUPPORT SERVICES. OBJECTIVE AND SUBJECTIVE EVALUATION OF THE EFFECTS OF A G-SEAT ON PILOT/SIMULATOR PERFORMANCE DURING A TRACKING TASK. PROCEEDINGS OF THE TENTH NTEC/INDUSTRY CONFERENCE, NTEC IH 294 NOV. 1977.

* ABSTRACT *

A SEAT CUSHION TO PROVIDE ACCELERATION CUES FOR AIRCRAFT SIMULATOR PILOTS HAS BEEN BUILT, PERFORMANCE TESTED, AND EVALUATED IN NASA LANGLEY'S DIFFERENTIAL MANEUVERING SIMULATOR. THE FOUR-CELL SEAT, USING A THIN AIR CUSHION WITH HIGHLY RESPONSIVE PRESSURE CONTROL, ATTEMPTS TO REPRODUCE THE SAME EVENTS WHICH OCCUR IN AN AIRCRAFT SEAT UNDER ACCELERATION LOADING. THE PRESSURE CONTROLLER PROVIDES SEAT CUSHION RESPONSES WHICH ARE CONSIDERED ADEQUATE FOR CURRENT HIGH-PERFORMANCE AIRCRAFT SIMULATIONS.

AN EXPERIMENT WAS DESIGNED TO EVALUATE THE EFFECT OF THE G-SEAT ON PILOT/SIMULATOR PERFORMANCE. THE STATISTICAL ANALYSIS OF DATA INDICATES THAT THE PILOT GETS INFORMATION FROM THE SEAT WHICH ALLOWS MORE PRECISE CONTROL OF THE SIMULATED AIRCRAFT. PILOT SUBJECTIVE DATA SUPPORT THE CONCLUSIONS OF THE STATISTICAL ANALYSIS.

ASHWORTH, B.R. AND FARRISH, R.V.
A VISUAL MOTION SIMULATOR FOR GENERAL AVIATION COMPENSATED WITH-
IN THE NONLINEAR ADAPTIVE WASHOUT FOR ACTUATOR LAG.
NASA LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA. PRESENTED AT
THE 'AIAA VISUAL AND MOTION SIMULATION CONFERENCE', AIAA PAPER
NO. 76-022, APRIL 26-28, 1976

* ABSTRACT *

A DESCRIPTION IS PRESENTED OF THE GENERAL AVIATION AIRCRAFT
SIMULATOR RECENTLY ACQUIRED BY THE LANGLEY RESEARCH CENTER,
SUMMARIZING THE COMPLEMENT OF INSTRUMENTS, RADIO/NAVIGATION
EQUIPMENT, CONTROL LOADING AND OTHER FEATURES. EMPHASIS IS
PLACED MAINLY ON THE TWO-DEGREE-OF-FREEDOM MOTION DRIVES
DEVELOPED FOR THIS SIMULATOR AND THE PRESENTATION OF THE
DYNAMIC RESPONSE OF THE MOTION SYSTEM (WITHOUT WASHOUT) IN
TERMS OF AMPLITUDE RATIO AND PHASE LAG AS A FUNCTION OF
FREQUENCY. THE NONLINEAR ADAPTIVE WASHOUT BASED ON CONTINUOUS
STEEPEST DESCENT OPTIMIZATION PRESENTS CUES IN PITCH RATE,
CLIMB, ROLL RATE, AND SWAY AND ALLOWS FOR ACTUATOR LAG
COMPENSATION.

W.C.A. AYLESBURY, ET AL - GROUND BASED FLIGHT SIMULATING APPARA-
TUS PATENT NO. 3,597,857
FILED FEB. 3, 1969 GRANTED AUG. 10, 1971

NO ABSTRACT

BAARSFEL, M. AND VANDORREN, J. P.
THE HYBRID SIMULATION OF AIRCRAFT MOTIONS IN A PILOTED MOVING-
BASE FLIGHT SIMULATOR.
TECHNISCHE HOOGESCHOOL, DELFT (NETHERLANDS)
AVAILABLE NTIS-PC A08/MF A01

* ABSTRACT *

THE MAIN TECHNICAL FEATURES OF THE GENERAL PURPOSE MOVING BASE
PILOTED FLIGHT SIMULATOR OF THE DEPARTMENT OF AERONAUTICS AND
SPACE ENGINEERING ARE DESCRIBED. DESCRIPTION OF THE HYBRID

COMPUTER, THE THREE-DEGREE-OF-FREEDOM MOTION SYSTEM, THE SIMULATOR COCKPIT, THE FLIGHT INSTRUMENTS, THE CONTROL FEEL SYSTEM, THE FLIGHT DIRECTOR/AUTOPILOT, AND THE VISUAL DISPLAY SYSTEM ARE INCLUDED. THE APPLICATION OF A SIMPLIFIED MATHEMATICAL MODEL TO SIMULATE AIRCRAFT DYNAMICS IN FLIGHT AND AFTER TOUCHDOWN IS DISCUSSED. SPECIAL ATTENTION IS GIVEN TO THE AERODYNAMIC EFFECTS OF FLAP AND LANDING GEAR EXTENSION, AERODYNAMIC GROUND EFFECT, THE SIMULATION OF THE LANDING LOADS ON THE AIRCRAFT AFTER TOUCHDOWN AND CONTROL FORCE FEEL SIMULATION. AN IMPORTANT ASPECT OF THIS PILOTED SIMULATOR IS ITS ABILITY TO PROVIDE REALISTIC MOTION CUES. SOLUTIONS TO THE PROBLEM OF GENERATING DRIVE COMMANDS FOR THE CONSTRAINED THREE-DEGREE-OF-FREEDOM MOTION SYSTEM ARE DISCUSSED. THE HYBRID COMPUTER PROGRAM, USED FOR THE SIMULATION OF THE APPROACH AND LANDING OF A TRANSPORT AIRCRAFT IS DESCRIBED ON THE BASIS OF SYSTEM FLOW CHARTS AND ANALOG DIAGRAMS.

BARET, M. SIX DEGREES OF FREEDOM LARGE MOTION SYSTEM FOR FLIGHT SIMULATORS; PRESENTED AT AGARD FLIGHT MECHANICS PANEL SPECIALISTS' MEETING ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS, BELGIUM, APRIL 24-27, 1978.

* ABSTRACT *

THE SPECIAL FEATURE OF THE SIX DEGREES OF FREEDOM LARGE MOTION SYSTEM DESCRIBED IN THIS DOCUMENT IS THE LONG-STROKE, HOLLOW-ROD JACK WITH HYDROSTATIC BEARINGS.

THIS TECHNIQUE PROVIDES AN IMPROVED PERFORMANCE AND CONSIDERABLY REDUCES THE LEVEL OF THE UNWANTED ACCELERATIONS NORMALLY GENERATED BY MOTION SYSTEMS, WHILE OFFERING NEW POSSIBILITIES IN THE STUDY OF CONTROL LAWS.

BARRETT, G.V., CABE, P.A., THORNTON, C.L. AND KEEBER, H.E. EVALUATION OF A MOTION SIMULATOR NOT REQUIRING COCKPIT MOTION. 'HUMAN FACTORS', 1969, 11(3), 239-244.

* ABSTRACT *

A NEW TYPE OF SYSTEM FOR SIMULATING MOTION CUES EMPLOYS A SEAT MADE UP OF SIX DIFFERENTIALLY INFLATABLE SECTIONS. THIS DEVICE WAS EVALUATED WITH A SAMPLE OF EIGHT PILOTS IN A COCKPIT MOCK-UP. SEAT MOTION SIGNIFICANTLY INCREASED RATED REALISM FOR A SERIES OF SIX MANEUVERS. WHEN SUBJECTS WERE PRESENTED WITH MOTION CUES WHILE THEIR EYES WERE CLOSED, CORRECT IDENTIFICATION OF MANEUVERS AVERAGED 85% AND RATED CONFIDENCE IN JUDGMENTS AVERAGED 76%. THE SEAT WAS CONSIDERED TO BE A RELATIVELY SIMPLE, LOW-COST METHOD FOR SIMULATING MOTION CUES.

BARNETT, G.V. AND THORNTON, C.L. 'RELATIONSHIP BETWEEN PERCEPTUAL STYLE AND SIMULATOR SICKNESS'. 'JOURNAL OF APPLIED PSYCHOLOGY', 1964, 52, 4, 304-308.

* ABSTRACT *

SIMULATOR SICKNESS WAS HYPOTHEZIZED TO BE CAUSED BY THE CONFLICT BETWEEN THE VISUAL PRESENTATION OF APPARENT MOTION AND THE LACK OF ANY CORRESPONDING BODY SENSATION OF MOTION. THE HYPOTHESIS WAS TESTED BY CORRELATING INDIVIDUAL DIFFERENCES IN SCORES ON THE RBD AND FRAME TEST (RFT; WHICH MEASURES ACCURACY OF ADJUSTMENT OF A ROD TO TRUE VERTICAL UNDER CONDITIONS OF VISUAL-KINESTHETIC CONFLICT) AND DEGREE OF SIMULATOR SICKNESS. THE DATA FOR SERIES 3 OF THE RFT AND THE INDEXES OF SICKNESS WERE BEST REPRESENTED BY HYPERBOLIC FUNCTIONS YIELDING CORRELATIONS OF .40-.52. IMPLICATIONS FOR SIMULATION TECHNOLOGY AND FOR A GENERAL CONFLICT OF CUE THEORY ARE DISCUSSED WITH EMPHASIS ON SUPPORTING EVIDENCE FROM SEVERAL AREAS OF INVESTIGATION.

BECK, I.J. THE EFFECT OF SPURIOUS ANGULAR ACCELERATIONS ON TRACKING IN DYNAMIC SIMULATION
DEPARTMENT OF PSYCHOLOGY, SAN JOSE UNIVERSITY, SAN JOSE, CALIF,
HUMAN FACTORS, 1974, 16(4), 423-431.

* ABSTRACT *

A LABORATORY STUDY WAS CONDUCTED TO INVESTIGATE THE EFFECT OF VARIOUS SPURIOUS SIMULATOR YAW MOTIONS ON A PILOT'S CONTROL PERFORMANCE. A SECOND OBJECTIVE WAS TO COMPARE THE EFFICIENCY OF STATIC AND DYNAMIC SIMULATOR TRACKING IN PREVIOUSLY UNEXAMINED VEHICLE DYNAMICS. TWELVE AIRLINE PILOTS SERVED AS SUBJECTS IN A MOVING-BASE FLIGHT SIMULATOR UNDER CONGRUENT-MOTION, SPURIOUS-MOTION, AND NO-MOTION CONDITIONS. THE RESULTS INDICATED A SIGNIFICANT INCREASE IN THE AMOUNT OF ERROR WITH INCREASING LEVELS OF SPURIOUS MOTION DURING THE INITIALLY ADMINISTERED SERIES OF TRIALS. THE INFLUENCE OF SPURIOUS MOTION, HOWEVER, WAS ABSENT IN A SECOND SERIES OF TRIALS. THE DATA SUGGEST THAT THE PILOTS LEARNED TO COMPENSATE IN THEIR PERFORMANCE FOR THE SPURIOUS INPUTS. IT WAS ALSO FOUND THAT CONGRUENT VISUAL AND ROTATIONAL CUEING PRODUCED SUPERIOR PERFORMANCE TO THAT OF TRACKING WITH VISUAL INFORMATION ALONE.

BELSLEY, S.E. MAN-MACHINE SYSTEM SIMULATION FOR FLIGHT VEHICLES' IEEE TRANSACTIONS. HUMAN FACTORS IN ELECTRON. HEE-4-14, 1963.

* ABSTRACT *

A PROCEDURE FOR CONDUCTING A MEANINGFUL SIMULATION OF A MAN.

MACHINE SYSTEM IS PRESENTED AND ILLUSTRATED BY VARIOUS SPECIFIC EXAMPLES. THE RELATIONSHIP OF THE VARIOUS TYPES OF SIMULATORS TO THEIR USE IS OUTLINED AND DESIRABLE DETAILED CHARACTERISTICS ARE DELINEATED. THE TRADEOFFS BETWEEN SIMULATOR COMPLEXITY, REALISM AND THE INTERRELATION OF VARIOUS FEEDBACK SENSING CUES (MOTION, VISUAL OR TACTILE) ARE DISCUSSED AND THE NECESSITY OF VALIDATING THE SIMULATION BY USE OF A VARIABLE STABILITY AND VARIABLE CONTROL SYSTEM AIRCRAFT IS NOTED. IT IS SHOWN THAT AS THE PROBLEM TO BE STUDIED BECOMES MORE COMPLICATED OR THE QUESTIONS ASKED OF THE SIMULATION BECOME MORE QUANTITATIVE, THE SIMULATOR CHARACTERISTICS MUST BECOME MORE FLIGHT-LIKE, SINCE IN THE LAST ANALYSIS THE BEST PLACE TO ASK THE QUESTION IS WHEN THE PILOT AND THE VEHICLE ARE IMMERSED IN THE TRUE ENVIRONMENT (I.E., FLIGHT).

RELSTERLING, C.A. AND MURPHY, E.I. 'DESIGN STUDIES OF A MOTION SYSTEM FOR THE VTOL SIMULATION FACILITY'. FRANKLIN INSTITUTE FOR RESEARCH LABS, PHILADELPHIA FOR THE NAVAL TRAINING EQUIPMENT CENTER. REPORT NO. FIRM-F-C4270-01, FEBRUARY 1976. AD-A024-734

* ABSTRACT *

THIS REPORT DOCUMENTS THE DESIGN STUDIES INVOLVED IN DETERMINING THE BEST CONFIGURATION FOR A NEW INTEGRATED DISPLAY AND MOTION SYSTEM FOR THE NAVAL TRAINING EQUIPMENT CENTER VTOL SIMULATION FACILITY. FOUR CANDIDATE SCHEMES ARE CONSIDERED AND TWO ARE CHOSEN FOR DETAILED COMPARISON. THE RESULT IS THE RECOMMENDATION FOR A NEW SIX-DEGREE-OF-FREEDOM MOTION SYSTEM SUSPENDED FROM A LOW PROFILE FOUNDATION STRUCTURE.

RENDAT, J.S.

MATHEMATICAL ANALYSIS AND ANALOGUE SIMULATION OF ATMOSPHERIC TURBULENCE GUST VELOCITIES. 'JOURNAL OF AERONAUTICAL SCIENCES', VOL 24, JANUARY 1957.

* ABSTRACT *

AVAILABLE MEASUREMENTS OF ATMOSPHERIC TURBULENCE GUST VELOCITIES BY CLEMENTSON, DOUGLAS AIRCRAFT COMPANY, INC., PERSONNEL, NACA PERSONNEL, SUMMERS, AND CHILTON INDICATE THAT OVER A CONSIDERABLE RANGE OF FREQUENCIES, THE POWER SPECTRAL DENSITY FUNCTION $G(w)$ MAY BE REPRESENTED BY A C/w^2 TYPE OF CURVE. FOR LOWER FREQUENCIES, $G(w)$ IS MORE COMPLICATED, APPROACHING A CONSTANT VALUE AS w APPROACHES ZERO.

RENFARI, R.C. 'PERCEPTUAL VERTIGO: A DIMENSIONAL STUDY'. 'PERCEPTUAL AND MOTOR SKILLS', 1964, 18, 633-639.

* ABSTRACT *

NINE S'S WERE USED IN AN EXPERIMENT TO DETERMINE THE EFFECTS OF PERIPHERAL FLICKER AND THE DEGREE OF STRUCTURE OF THE STIMULUS FIELD UPON THE INCIDENCE AND DEGREE OF VERTIGO. THE GROUPS OF S'S WERE DEFINED AS: (A) SUSCEPTIBLE, (B) NON-SUSCEPTIBLE, AND (C) A HIGHLY TRAINED AVIATOR GROUP. VISUAL PRESENTATION OF THE STIMULI WAS ACCOMPLISHED BY MEANS OF A HEMISPHERAL SCENE AND A WIDE-ANGLE LENS SYSTEM. S'S VERBAL RESPONSES WERE RECORDED AND ANALYZED. THE GROUPS RESPONDED WITH A GREATER DEGREE OF VERTIGINOUS RESPONSE TO THE STIMULI OF PERIPHERAL FLICKER IN A FIELD OF LOW STRUCTURE.

BENJAMIN, P. VISUAL AND MOTION CUES IN HELICOPTER FLIGHT, MIT, MAN-VEHICLE CONTROL LAB, THESIS NO. T-66-1, JANUARY 1966.

* ABSTRACT *

THIS PAPER INVESTIGATES THE RELATIVE IMPORTANCE OF MOTION AND VISUAL CUES ON THE ABILITY OF EXPERIENCED PILOTS AND NON-FLYING SUBJECTS TO CONTROL A HOVERING HELICOPTER. IT EXAMINES THE INTERACTION OF THESE DIFFERENT FORMS OF INPUT INFORMATION AND THE METHODS BY WHICH THEY ARE UTILIZED BY THESE TWO CLASSES OF SUBJECTS. THE METHOD BY WHICH CONTROL OF SUCH A HIGH-ORDER SYSTEM AS A HELICOPTER IS AFFECTED IS DISCUSSED AND A THEORY OF THIS IS ADVANCED. A SIMPLE VISUAL DISPLAY SYSTEM WHICH PROVIDES A UNIQUE DESCRIPTION OF POSITION AND ATTITUDE WITH RESPECT TO A DEFINED AXIS SYSTEM AND UTILIZES RELATIVELY INEXPENSIVE AND AVAILABLE ANALOG EQUIPMENT IS PRESENTED.

BERGERON, HUGH P.
AEROSPACE TECHNOLOGIST, NASA LANGLEY RESEARCH CENTER HAMPTON, VA
70 - 352.
THE EFFECTS OF MOTION CUES ON COMPENSATORY TRACKING TASKS
AIAA CONF. MAR 16-18 1970 (CAPE)

* ABSTRACT *

THE DATA PRESENTED ARE TAKEN FROM TESTS THAT WERE DESIGNED TO DEFINE AREAS WHERE MOTION CUES ARE BENEFICIAL IN CONTROLLING COMPENSATORY TRACKING TASKS AND TO DETERMINE SOME OF THE REQUIREMENTS OF THESE MOTION INPUTS. ONE AND TWO-AXIS TESTS WERE MADE WITH AND WITHOUT MOTION. TWO-AXIS TESTS WERE PERFORMED IN WHICH THE AMPLITUDE OF MOTION, AS COMPARED TO THE VISUAL INPUT, WAS VARIED FROM ONE RUN TO THE NEXT. THE RESULTS INDICATE THAT THE ADDITION OF MOTION HAD LITTLE OR NO EFFECT ON THE CONTROL OF THE SINGLE-AXIS TASKS THAT WERE TESTED. HOWEVER, MOTION DID MAKE A DIFFERENCE IN THE MORE DIFFICULT TWO-AXIS TASKS. ALSO, THE DATA SHOW THAT A REDUCTION IN THE SCALE OF MOTION, IN THE TWO-AXIS TASKS, AS LITTLE AS 1/4 MOTION

SCALE, PRODUCES RESULTS COMPARABLE TO WHEN FULL SCALED MOTION WAS USED.'

BERGERON, H. F.

'INVESTIGATION OF MOTION REQUIREMENTS IN COMPENSATORY CONTROL TASKS.'

'IEEE TRANSACTIONS ON MAN MACHINE SYSTEMS'

VOL MMS-11, NO. 2, JUNE 1970.

* ABSTRACT *

TESTS CONSISTING OF ONE AND TWO-AXIS CLOSED-LOOP TRACKING TASKS WITH AND WITHOUT MOTION, HAVE BEEN MADE TO DEFINE SOME AREAS WHERE MOTION CUES ARE BENEFICIAL. TESTS WERE MADE WITH REDUCED SCALING ON THE MOTION INPUT TO INVESTIGATE THE MINIMUM REQUIREMENTS OF MOTION CUES IN THOSE TESTS WHERE MOTION WAS FOUND TO BE OF ASSISTANCE.

FOR THE SET OF CONDITIONS TESTED, LITTLE OR NO DIFFERENCE IN THE MEASUREMENT CRITERIA WAS OBSERVED IN THE SINGLE-AXIS MOTION/NO MOTION RUNS. SIMILAR RESULTS WERE OBTAINED WHEN COMPARING TWO SINGLE-AXIS TESTS WITH DIFFERENT PITCH ORIENTATION. THE TWO-AXIS TESTS, WHICH CONSISTED OF PITCH AND YAW AND PITCH AND ROLL, DID HOWEVER, PRODUCE A DIFFERENCE IN THE ERROR MEASUREMENT IN THE MOTION/NO MOTION COMPARISON. A DECREASE IN NORMALIZED TRACKING ERROR AND IN INCREASE IN CLOSED-LOOP SYSTEM FREQUENCY WERE OBSERVED WHEN MOTION WAS ADDED.

TESTS WERE ALSO RUN, IN PITCH AND YAW ONLY, IN WHICH THE SCALE OF THE MOTION INPUT WAS REDUCED. THESE TESTS WERE PERFORMED BY THE SUBJECT IN SEQUENCE STARTING WITH NO MOTION ALL THE WAY TO FULL MOTION AND BACK DOWN TO NO MOTION. EACH MOTION SCALE CONDITION (NONE, 1/16, 1/8, 1/4, 1/2 AND FULL) CONSTITUTED A TEST. THE NORMALIZED TRACKING ERROR REMAINED CONSTANT FOR FULL, 1/2 AND 1/4 MOTION SCALING BUT INCREASED WITH A FURTHER REDUCTION IN MOTION SCALING.

BERGERON, H.F. AND ADAMS, J.J. MEASURED TRANSFER FUNCTIONS OF PILOTS DURING TWO-AXIS TASKS WITH MOTION. NASA TN D-2177, 1964

* ABSTRACT *

FOUR PILOTS CONTROLLED A SPHERE ATTITUDE DISPLAY IN PITCH AND YAW (STATIC COCKPIT) OR PITCH AND ROLL (DYNAMIC COCKPIT). ANALOGUE AUTOPILOT SYSTEM MATCHING PILOT OUTPUT IN AN ATTEMPT TO DESCRIBE HIS TRANSFER FUNCTION, DEMONSTRATED THAT COCKPIT MOTION REDUCED HIS GAIN VARIABILITY IN BOTH AXES.

BERGERON, H.P., ADAMS, J.J. AND FURT, G.J. THE EFFECTS OF MOTION CUES AND MOTION SCALING ON ONE- AND TWO-AXIS COMPENSATORY CONTROL TASKS. NASA TN-D-6110, 1971.

* ABSTRACT *

SUBJECTS

4 NASA TEST PILOTS AND 4 ENGINEERS WITH TRACKING EXPERIENCE.

EQUIPMENT

THE TESTS WERE MADE IN A ONE-MAN COCKPIT MOCK-UP FITTED WITH A THREE-AXIS ATTITUDE INDICATOR. THE CONTROLS WERE MANIPULATED BY A SIDE-ARM STICK MOUNTED ON THE SUBJECT'S RIGHT. THE MOTION SYSTEM HAD CERTAIN LIMITATIONS. FOR THE SINGLE-AXIS TASK THE EQUIPMENT COULD BE USED IN THREE AXES (PITCH, YAW, ROLL). FOR THE TWO-AXIS IT COULD ONLY BE USED FOR PITCH AND YAW OR FOR PITCH AND ROLL. THE TESTS WITH PITCH AND YAW WERE PERFORMED WITH THE SUBJECT IN A SEATED POSITION, AND FOR PITCH AND ROLL MOTION THE SUBJECT WAS SUPINE.

METHOD AND RESULTS

AFTER SIMULATOR PRACTICE, EACH SUBJECT DID A SERIES OF DATA RUNS, EACH LASTING THREE MINUTES, TO FIND THE EFFECTS OF ANGULAR MOTION ON COMPENSATORY CONTROL TASKS. THEY INCLUDED ONE- AND TWO-AXIS TASKS WITH AND WITHOUT MOTION. BOTH FULL-SCALE MOTION AND REDUCED-SCALE MOTION (TESTS IN WHICH THE SCALE OF MOTION, COMPARED TO THE VISUAL INPUT, WAS REDUCED) WERE EXAMINED. THE REDUCED-SCALE MOTION TESTS WERE PERFORMED TO INVESTIGATE THE MINIMUM REQUIREMENTS OF MOTION INPUTS IN THOSE TESTS WHERE MOTION WAS FOUND TO BE BENEFICIAL. LITTLE OR NO DIFFERENCE IN THE ERROR MEASUREMENTS WERE OBSERVED IN THE SINGLE-AXIS MOTION/NO MOTION TESTS. THE TWO-AXIS TESTS (ENVELOPING PITCH AND YAW OR PITCH AND ROLL MOTION) DID, HOWEVER, PRODUCE A DIFFERENCE IN THE ERROR MEASUREMENTS IN THE MOTION/NO MOTION COMPARISONS. A DECREASE IN NORMALIZED TRACKING ERROR AND AN INCREASE IN THE CLOSED-LOOP SYSTEM FREQUENCY WERE OBSERVED WHEN MOTION WAS ADDED. THE REDUCED-SCALE MOTION TESTS WERE MADE WITH THE TWO-AXIS PITCH AND YAW TASK. THESE TESTS WERE DONE IN A SEQUENCE STARTING WITH NO MOTION, ALL THE WAY TO FULL-SCALE MOTION, AND BACK TO NO MOTION. EACH MOTION SCALE CONDITION (NONE, 1/16, 1/8, 1/4, 1/2, AND FULL) CONSTITUTED A TEST. THE NORMALISED TRACKING ERROR REMAINED CONSTANT FOR FULL, 1/2, AND 1/4 MOTION SCALING BUT INCREASED WITH A FURTHER REDUCTION IN MOTION SCALING.

CONCLUSIONS

MOTION MAY OR MAY NOT BE A HELP IN CONTROLLING A COMPENSATORY CONTROL TASK, DEPENDING ON THE DIFFICULTY OF THE TASK AND ON THE REQUIREMENTS OF THE MISSION. IN GENERAL, ANGULAR MOTION IS

HELPFUL IF:

1. THE CHARACTERISTICS OF THE PLANT DYNAMICS ARE SUCH THAT THE SUBJECT CAN USE THE LEAD INFORMATION INHERENT TO MOTION TO TIGHTEN THE CONTROL LOOP, I.E. INCREASE THE SYSTEM FREQUENCY WITHOUT DECREASING THE DAMPING RATIO, OR
2. TWO OR MORE VARIABLES ARE BEING CONTROLLED AND THE MOTION

INPUTS ALLOW THE SUBJECTS TO BE ALERT TO CHANGES IN THE VARIABLE(S) NOT BEING CLOSELY MONITORED VISUALLY AT THE TIME.

BERGERAN, H.F. AND HOLT, J.D. MOTION-BASE SIMULATOR TESTS OF LOW FREQUENCY AIRCRAFT MOTION ON THE PASSENGER RIDE ENVIRONMENT. NASA TN-X-62464, 1975.

* ABSTRACT *

A LARGE AMPLITUDE MOTION SIMULATOR, THE NASA-LANGLEY REAL-TIME DYNAMIC SIMULATOR, WAS USED TO STUDY PASSENGER RIDE QUALITY ACCEPTANCE OF LOW FREQUENCY AIRCRAFT MOTION. THE MOTION SIMULATED HAD PREVIOUSLY BEEN MEASURED DURING ROUTINE AIRLINE FLIGHTS. PASSENGER SUBJECTIVE RATINGS OF THE SIMULATION CONSISTED OF BOTH NAIVE SUBJECTS (PEOPLE WHO HAD NEVER PREVIOUSLY TAKEN PART IN RIDE QUALITY TESTS) AND EXPERIENCED SUBJECTS (PEOPLE WHO HAD PARTICIPATED IN AIRCRAFT ENVIRONMENT TESTS). EACH SUBJECT WAS TESTED AT LEAST TWICE, THREE OF THE EXPERIENCED SUBJECTS WERE TESTED UP TO TWENTY TIMES.

CONCLUSIONS

1. THE AIRCRAFT MOTION WHICH PRODUCES SICKNESS CAN BE REALISTICALLY SIMULATED.
2. SIMULATOR MOTION CAN BE USED FOR EVALUATING LOW FREQUENCY AIRCRAFT MOTION IN PASSENGER RIDE QUALITY RESEARCH.
3. A SMALL NUMBER OF EXPERIENCED SUBJECTS CAN BE USED TO REPRESENT LARGER NUMBERS OF NAIVE SUBJECTS.
4. REPEATED RUNS WITH EXPERIENCED SUBJECTS SHOW NO APPARENT RUN-TO-RUN BIAS.

PERTHOZ, A., FAVARD, B., AND YOUNG, L. R.
PERCEPTION OF LINEAR HORIZONTAL SELF-MOTION INDUCED BY PERIPHERAL VISION (LINEARVECTION).
IN PRESS IN THE JOURNAL OF EXPERIMENTAL BRAIN RESEARCH.

* ABSTRACT *

THE BASIC CHARACTERISTICS OF LINEAR HORIZONTAL MOTION HAVE BEEN STUDIED. OBJECTIVE LINEAR MOTION WAS INDUCED BY MEANS OF A MOVING CART. VISUALLY INDUCED LINEAR MOTION PERCEPTION (LINEARVECTION) WAS OBTAINED BY PROJECTION OF MOVING IMAGES AT THE PERIPHERY OF THE VISUAL FIELD. IMAGE VELOCITY AND LUMINANCE THRESHOLDS FOR THE APPEARANCE OF LINEARVECTION HAVE BEEN MEASURED AND ARE IN THE RANGE OF THOSE FOR IMAGE MOTION DETECTION (WITHOUT SENSATION OF SELF MOTION) BY THE VISUAL SYSTEM. LATENCIES OF ONSET ARE AROUND 1 SECOND AND SHORT TERM ADAPTATION HAS BEEN SHOWN. THE DYNAMIC RANGE OF THE VISUAL ANALYSER AS JUDGED BY FREQUENCY ANALYSIS IS LOWER THAN FOR THE VESTIBULAR ANALYZER. CONFLICTING SITUATIONS IN WHICH VISUAL CUES CONTRADICT VESTIBULAR AND OTHER PROPRIOCEPTIVE CUES SHOW,

NAVTRAEQUIPCEN IH-298

IN THE CASE OF LINEARVECTION, A DOMINANCE OF VISION WHICH SUPPORTS THE IDEA OF AN ESSENTIAL ALTHOUGH NOT INDEPENDENT ROLE OF VISION IN SELF MOTION PERCEPTION.

HESOR, R. O.
'THE EFFECTS OF COCKPIT VERTICAL ACCELERATIONS ON A SIMPLE, PILOTED TRACKING TASK.'
'NORTH AMERICAN AVIATION REPORT'
NA-NA 61-47. LOS ANGELES, CALIFORNIA. APRIL 1961.
(ALSO IN 'HUMAN FACTORS', VOL. 3, 4, DEC 1961.)

* ABSTRACT *
BETTER PITCH CONTROL PERFORMANCE WHEN PITCH MOTION ADDED TO A STATIC SIMULATOR. MORE TRUE FOR PRECISE MANEUVERING (RATHER THAN FOR PRECISE MAINTENANCE OF STRAIGHT-AND-LEVEL FLIGHT).

THE REPORT PRESENTS THE RESULTS OF AN EXPERIMENTAL SIMULATION STUDY OF THE EFFECTS OF VERTICAL ACCELERATIONS ON THE ABILITY OF PILOTS TO TRACK A SIMPLE, ONE DIMENSIONAL RANDOM SIGNAL ON THE PILOT OPERATED DYNAMIC FLIGHT SIMULATOR OF THE COLUMBUS DIVISION OF NAA. IT WAS CONCLUDED THAT PILOTS COULD TRACK SIGNIFICANTLY BETTER WITH SIMPLE AIRCRAFT RESPONSE MOTION CUES. HOWEVER, WHEN GUSTS AND TURBULENCE WERE ADDED TO THE COCKPIT MOTION, PILOT PERFORMANCE WAS SIGNIFICANTLY DEGRADED. (AUTHOR)

REYBRY, E.J. S. C1 MOTION DRIVE PROGRAM. COMPUTER SCIENCES CORPORATION, MOUNTAIN VIEW, CA FOR NASA AMES PR 5-74 AUGUST 1974

* ABSTRACT *
THIS REPORT DESCRIBES A MOTION DRIVE PROGRAM FOR THE SIX DEGREE OF FREEDOM MOVING BASE SIMULATOR (S. 01) AT THE NASA-AMES RESEARCH CENTER. ITS PURPOSE IS TO PROVIDE DOCUMENTATION OF THE MOTION SYSTEM IMPLEMENTED ON THE EAI-8400 DIGITAL COMPUTER AND TO BE A GUIDE TO THE USE OF THIS PROGRAM. THE PROGRAM IS WRITTEN TO BE USED SPECIFICALLY WITH THE BASIC SYSTEM OF FLIGHT SIMULATION.

BILLINGS, C. E., EGGSPUEHLER, J. J., GERKE, R. J., CHASE, R. C. AND BRIGGS, G. E.
STUDIES OF PILOT PERFORMANCE AND STRESS IN STUDENT PILOTS.
ANNUAL PROGRESS REPORT, 1 MAR 69 - 28 FEB 70,
OHIO STATE UNIV. RESEARCH FOUNDATION,
COLUMBUS, OH, AD-271 383L, ALSO AD-260 522 L, MAR 1970.

* ABSTRACT *

THIS REPORT DESCRIBES THE RESULTS OF DETAILED ANALYSES OF DATA COLLECTED FROM FOUR STUDENT HELICOPTER PILOTS. TWO STUDENTS HAD FIXED WING PRIVATE PILOT LICENSES; THE OTHER TWO HAD NEVER FLOWN BEFORE BEGINNING THEIR TRAINING. THE SUBJECTS RECEIVED 20-25 HOURS OF INSTRUCTION FROM A FORMER U.S. ARMY INSTRUCTOR WHO UTILIZED THE PRE-SOLO PHASE OF THE ARMY PRIMARY HELICOPTER TRAINING CURRICULUM AS A TRAINING GUIDE. THE DATA INDICATED THAT ENGINE OR ROTOR RPM VARIABILITY IS A FAIRLY SENSITIVE AND RELIABLE INDEX OF MANEUVER DIFFICULTY AND OF PILOT SKILL. MEASUREMENT OF STUDENT HEART RATES INDICATE THAT STRESS EFFECTS WERE PRESENT DURING DUAL FLIGHT AND THAT THE AMOUNT OF STRESS INCREASED AS THE STUDENTS PROGRESSED THROUGH THEIR TRAINING. SOLO FLIGHT, ON THE OTHER HAND, BECAME LESS STRESSFUL WITH INCREASING EXPOSURE. ALL STUDENTS SHOWED MARKED STRESS EFFECTS DURING PPRR AND FAA FLIGHT CHECKS. THE OBSERVED STRESS EFFECTS APPEARED TO BE PRESENT WHETHER OR NOT THE STUDENT'S PERFORMANCE WAS IMPROVING DURING THE COURSE OF FLIGHT INSTRUCTION. (AUTHOR)

 BIRMINGHAM, H.P. AND TAYLOR, F.V. 'A DESIGN PHILOSOPHY FOR MAN-MACHINE CONTROL SYSTEMS'. SELECTED PAPERS ON HUMAN FACTORS IN THE DESIGN AND USE OF CONTROL SYSTEMS. EDITED BY WALLACE SINAICK, NEW YORK: DOVER PUBLICATIONS, INC. 1961.

* ABSTRACT *

EMPIRICAL EVIDENCE SUGGESTS THAT, AT LEAST FOR SHORT PERIODS OF ACTIVITY, THE SIMPLER THE TASKS IMPOSED UPON THE HUMAN OPERATOR OF A CONTROL SYSTEM, THE MORE PRECISE AND LESS VARIABLE BECOME HIS RESPONSES. THIS LEADS TO THE VIEW THAT OPTIMAL MAN-MACHINE CONTROL SYSTEM PERFORMANCE CAN BE OBTAINED ONLY WHEN THE MECHANICAL COMPONENTS OF THE SYSTEM ARE DESIGNED SO THAT THE HUMAN NEED ACT ONLY AS A SIMPLE AMPLIFIER. WAYS AND MEANS ARE DESCRIBED FOR ACHIEVING SUCH DESIGN THROUGH 'UNBURDENING' (RELIEVING THE OPERATOR OF THE TASK OF ACTING AS AN INTEGRATOR) AND 'QUICKENING' (PROVIDING THE OPERATOR WITH IMMEDIATE KNOWLEDGE OF THE EFFECTS OF HIS OWN RESPONSES). AIDED TRACKING IS DISCUSSED IN LIGHT OF THESE TWO CONCEPTS AND IS RELATED TO VARIOUS EFFORTS TO IMPROVE THE STABILITY OF MAN-MACHINE SYSTEMS THROUGH THE USE OF SPECIAL EQUALIZATION NETWORKS.

 RISCH, A. - AIR PILOT TRAINING DEVICE AND THE LIKE
 PATENT NO. 1,791,655
 FILED DEC. 5, 1929 GRANTED FEB. 10, 1931

NO ABSTRACT

BLISS, J. C.
INFORMATION PRESENTATION TO THE TACTILE AND KINESTHETIC SENSES.
IN BENNETT, E., DEGAN, J. AND SPIEGEL, J. (EDS).
HUMAN FACTORS IN TECHNOLOGY.
HUMAN FACTORS SOCIETY, MC GRAW-HILL: NEW YORK, 1963.

* ABSTRACT *

THE OBJECTIVE OF THIS CHAPTER IS TO REVIEW BRIEFLY SOME OF THE
POSSIBILITIES AND LIMITATIONS OF INFORMATIONAL DISPLAYS FOR THE
TACTILE AND KINESTHETIC SENSES AND TO REPORT ON SOME RECENT
WORK DONE IN THE AREA.

BANNER, R.H. SPATIAL DISORIENTATION - CURRENT CONCEPTS AND
AEROMEDICAL IMPLICATIONS. REVIEW 7-63, USAF SCHOOL OF AEROSPACE
MEDICINE, AEROSPACE MEDICAL DIVISION (AFSC), BROOKS AIR FORCE
BASE, TEXAS, AUG. 1963.

* ABSTRACT *

THIS REVIEW DEFINES MANY TYPES OF SPATIAL DISORIENTATION AND
VARIOUS ASPECTS OF THE PROBLEM AREA DISCUSSED. THE RECOGNITION
OF THE IMPORTANCE OF SPATIAL DISORIENTATION IN CAUSING AIRCRAFT
ACCIDENTS AND THE USE OF COUNTERMEASURES THROUGH TRAINING ARE
EMPHASIZED. SPECIAL APPARATUS FOR TRAINING TO ENDURE VESTIBULAR
IRRITATIONS ARE DESCRIBED AND ILLUSTRATED. THESE INCLUDE THE
TRAMPOLINE, REN WHEEL, LOOPING DEVICE, 4-POLE SWING, AND THE
RUGGLES ORIENTOR.

BRAMAN, C., YOUNG, L.R., AND CURRY, R.E. SENSORY MECHANISM
MODELLING AFHRL-TR-77-70
ADVANCED SYSTEMS DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY,
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433 OCTOBER 1977

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO MODEL HUMAN MOTION AND ORIENTA-
TION SENSING MECHANISMS SO THAT SIMULATOR MOTION CUEING SYSTEMS
CAN BE DESIGNED TO TAKE FULL ADVANTAGE OF THE CHARACTERISTICS OF
THESE SENSORY MECHANISMS. INDIVIDUAL MODELS FOR VESTIBULAR,
VISUAL, TACTILE, AND PROPRIOCEPTIVE SENSORS HAVE BEEN EITHER
ADAPTED FROM PREVIOUS MODELLING WORK OR FORMULATED FROM AVAIL-
ABLE PSYCHOPHYSICAL AND NEUROPHYSIOLOGICAL DATA. A COMPUTER
AIDED LITERATURE SEARCH WAS CONDUCTED TO HELP IDENTIFY MATERIAL
IN THE AREA OF MECHANORECEPTOR SYSTEMS, AND THE RESULTING BIB-
LIOGRAPHY IS INCLUDED IN THE REPORT.

A COMPOSITE MODEL STRUCTURE HAS BEEN PROPOSED, USING A KALMAN
FILTER BLENDING TECHNIQUE TO INTEGRATE INFORMATION FROM THE
DIFFERENT SENSORY MODALITIES INTO A SINGLE ESTIMATE OF STATE.

THE KALMAN FILTER REPRESENTS THE PRESUMED FUNCTION OF NEURAL CENTRAL PROCESSING. THE MODEL HAS BEEN IMPLEMENTED IN THE FORM OF A DIGITAL COMPUTER PROGRAM, AND PROMISING PRELIMINARY RESULTS, IN QUALITATIVE AGREEMENT WITH KNOWN HUMAN RESPONSES, HAVE BEEN OBTAINED USING ONLY VESTIBULAR MODEL COMPONENTS.

ONGOING WORK IS DIRECTED AT EXERCISING THE NONVESTIBULAR MODALITIES, PERFORMING THOROUGH VALIDATION AND EXERCISE OF THE ENTIRE MODEL, AND EXTENDING THE MODEL WHERE POSSIBLE. MODIFICATIONS ARE EXPECTED AS THIS WORK IS PURSUED.

PARAH, J.D. HUMAN DYNAMIC ORIENTATION MODEL APPLIED TO MOTION SIMULATION. MASTER'S THESIS, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 1976.

* ABSTRACT *

THE ORMSBY MODEL OF DYNAMIC ORIENTATION, IN THE FORM OF A DISCRETE TIME COMPUTER PROGRAM, HAS BEEN USED TO PREDICT NON-VISUALLY INDUCED SENSATIONS DURING AN IDEALIZED COORDINATED AIRCRAFT TURN. IT WAS FOUND THAT ATTITUDE AND ANGULAR RATE PERCEPTIONS MAY BE CONTRADICTORY AND FURTHERMORE, IN A THREE ROTATIONAL DEGREE OF FREEDOM SIMULATOR, IT IS IMPOSSIBLE TO DUPLICATE BOTH SIMULTANEOUSLY. TO PREDICT SIMULATION FIDELITY, A SIMPLE SCHEME WAS DEVISED USING THE ORMSBY MODEL TO ASSIGN PENALTIES FOR INCORRECT ATTITUDE AND ANGULAR RATE PERCEPTIONS. WITH THIS SCHEME, IT WAS DETERMINED THAT A THREE ROTATIONAL DEGREE OF FREEDOM SIMULATION SHOULD PROBABLY REMAIN FAITHFUL TO THE ATTITUDE PERCEPTION EVEN AT THE EXPENSE OF INCORRECT ANGULAR RATE SENSATIONS. IMPLEMENTING THIS STRATEGY, A SIMULATION PROFILE FOR THE IDEALIZED TURN WAS DESIGNED FOR A LINK GAT-1 TRAINER. USE OF A SIMPLE OPTOKINETIC DISPLAY WAS PROPOSED AS AN ATTEMPT TO IMPROVE THE FIDELITY OF ROLL RATE SENSATIONS.

TWO OPEN LOOP SUBJECTIVE TASKS WERE DESIGNED, TO OBTAIN ATTITUDE AND ROLL RATE PERCEPTION INDICATIONS. A SERIES OF EXPERIMENTS WERE PERFORMED IN OUR MODIFIED LINK TRAINER TO TEST THE EFFECTIVENESS OF THE TASKS AND TO CHECK MODEL PREDICTIONS AND VISUAL DISPLAY EFFECTS.

PERKENHAGEN, J.M. ROTARY ACCELERATION OF A SUBJECT INHIBITS CHOICE REACTION TIME TO MOTION IN PERIPHERAL VISION. JOURNAL OF EXPERIMENTAL PSYCHOLOGY, VOL. 102, '31, 484-487, 1974.

* ABSTRACT *

THE EFFECT OF SIS ROTARY ACCELERATION UPON CHOICE REACTION TIME (RT) TO AN ACCELERATING TARGET IN PERIPHERAL VISION WAS THE CENTRAL ISSUE IN THE EXPERIMENT, WITH THE LEVEL OF ACCELERATION AND

THE VIEWING ANGLE OF THE VISUAL TARGET AS VARIABLES. TWELVE PILOTS WERE TESTED IN A ROTATION DEVICE UNDER CONDITIONS OF VISUAL STIMULATION ALONE AND VISUAL-PLUS-ROTARY STIMULATION. THE PILOTS RESPONDED TO THE DIRECTION OF THE VISUAL MOTION BY MOVING A HAND CONTROLLER TO THE RIGHT OR LEFT. VISUAL-PLUS-ROTARY STIMULATION PRODUCED LONGER CHOICE RTS THAN THE VISUAL STIMULATION ALONE. CHOICE RT WAS INVERSELY RELATED TO THE LEVEL OF ACCELERATION AND DIRECTLY PROPORTIONAL TO THE VIEWING ANGLE. THE FINDINGS ARE DISCUSSED IN CONNECTION WITH THEORIES OF DOUBLE STIMULATION AND INTERSENSORY EFFECTS.

BRILLACE, F.H. 'FLIGHT SIMULATOR MOTION, ITS ENHANCEMENT AND POTENTIAL FOR FLIGHT CREW TRAINING'. CAE INDUSTRIES REPRINT, CA 1965.

* ABSTRACT *

PILOTS IN SIMULATORS WITH MOTION SYSTEMS PERFORM THEIR TASKS MORE PRECISELY, WITH LESS TIME LAG, AND WITH HIGHER FREQUENCY COMPONENTS IN THE CONTROL MOTIONS THAN THEY DO IN SIMULATORS WITHOUT MOTION SYSTEMS. THE WAY PILOTS PERFORM IN SIMULATORS WITH MOTION CUES IS CLOSER TO THE WAY THEY PERFORM IN THE AIRCRAFT. TRAINING IN SIMULATORS WITHOUT MOTION TENDS TO HAVE A NEGATIVE INITIAL OR FIRST SHOT TRANSFER TO THE AIRCRAFT.

ALSO IN PROCEEDINGS OF THIRD INTERNATIONAL SIMULATION AND TRAINING CONFERENCE,
SOCIETY OF AUTOMOTIVE ENGINEERS,
NEW YORK CITY
APRIL 24-27, 1967, 60-65

BROWSE, DAVID K.
AIR FORCE FLIGHT DYNAMICS LAB WRIGHT-PATTERSON AFB, OH
70-354
A LIMITED COMPARISON BETWEEN IN-FLIGHT SIMULATION AND GROUND BASE SIMULATION AIAA CONF MAR 16-18 1970 (CAPE)

* ABSTRACT *

A SUMMARY OF THE RESULTS OF PAST AND THE INTENT OF CURRENT EFFORTS, SUPPORTED BY THE AIR FORCE DYNAMICS LABORATORY DIRECTED TOWARD THE IDENTIFICATION OF SIGNIFICANT DIFFERENCES WHICH EXIST BETWEEN GROUND-BASED AND IN-FLIGHT SIMULATION, ARE PRESENTED. THE PAST EFFORTS HAVE USED THE VARIABLE STABILITY IN-33 AIRCRAFT AS BOTH AN IN-FLIGHT AND A GROUND-BASED SIMULATOR. IN THIS MANNER, THE EVALUATION PILOTS HAVE THE SAME COCKPIT AND FEEL SYSTEM ENVIRONMENT FOR BOTH GROUND-BASED AND IN-FLIGHT SIMULATION. CONCLUSIONS ARE DRAWN REGARDING THE VARIATION IN PILOT RATING AND PILOT INDUCED OSCILLATION RATING

WITH AND WITHOUT AIRCRAFT MOTION. AN OUTLINE OF THE INTENT AND DIRECTION OF A CURRENT CONTRACTED EFFORT AND A PARALLEL IN-HOUSE INVESTIGATION DEALING WITH AIRCRAFT DYNAMIC SIMILITUDE RELATED TO A FUTURE IN-FLIGHT SIMULATOR ARE ALSO PRESENTED. INTERIM RESULTS OF THESE EFFORTS MAY BE AVAILABLE FOR ORAL PRESENTATION AT THE CONFERENCE. (AUTHOR)

BRANDT, T.F., DICIGANS, J.M., AND KOENIG, E., 'DIFFERENTIAL EFFECTS OF CENTRAL VERSUS PERIPHERAL VISION ON EGOCENTRIC AND EXOCENTRIC MOTION PERCEPTION', EXP BRAIN RES 16 (1973) 476-491.

* ABSTRACT *

OPTOKINETIC STIMULI ALLOW FOR TWO PERCEPTUAL INTERPRETATIONS. THE OBSERVER MAY PERCEIVE HIMSELF AS BEING STATIONARY IN A MOVING SURROUND (EGOCENTRIC MOTION PERCEPTION) OR HE MAY EXPERIENCE AN ILLUSION OF SELF-MOTION, SO THAT THE ACTUALLY MOVING SURROUNDINGS APPEAR TO BE STABLE (EXOCENTRIC MOTION PERCEPTION).

RESULTS 1. CIRCULAR MOTION OF THE ENTIRE SURROUNDINGS (ROTATING DRUM INVARIABLY LEADS TO AN APPARENT SELF-ROTATION (CIRCULARVECTION: CV), WHICH IS INDISTINGUISHABLE FROM AN ACTUAL CHAIR ROTATION.

2. FOLLOWING STIMULUS ONSET, CV BEGINS AFTER A FEW SECONDS LATENCY AND SLOWLY INCREASES ITS APPARENT VELOCITY UNTIL ITS SATURATION. CV MAY OUTLAST THE VISUAL STIMULUS BY AS MUCH AS 30 SEC. LATENCIES ARE INDEPENDENT OF STIMULUS VELOCITY.

3. EVEN WITH DRUM ACCELERATIONS UP TO 15 DEGREES PER SECOND SQUARED, STATIONARY SUBJECTS CANNOT INFER FROM THE LACK OF VESTIBULAR INPUT THAT ONLY THE DRUM IS ROTATING.

4. WITH STIMULATION OF THE ENTIRE VISUAL FIELD OR SUFFICIENTLY LARGE PARTS OF THE PERIPHERAL RETINA, THE VELOCITY OF APPARENT SELF-ROTATION MATCHES STIMULUS SPEED UP TO 90-120 DEGREES PER SECOND. AT HIGHER SPEEDS, CV VELOCITY LAGS BEHIND STIMULUS SPEED AND RESULTS IN ADDITIONAL EGOCENTRIC MOTION PERCEPTION.

5. MASKING THE CENTRAL VISUAL FIELD BY BLACK DISKS UP TO 120 DEGREES IN DIAMETER SCARCELY DIMINISHES CV. CONVERSELY, IF PERIPHERAL VISION IS PRECLUDED, STIMULATION OF THE CENTRAL FIELD UP TO 30 DEGREES IN DIAMETER RESULTS IN EXCLUSIVE EGOCENTRIC MOTION PERCEPTION OF THE SURROUND. WITH A CENTRAL AND PERIPHERAL STIMULUS EQUIVALENT IN AREA, THE PERIPHERAL STIMULUS PREDOMINATES CV.

6. SIMULTANEOUS PRESENTATION OF CONFLICTING CENTRAL AND PERIPHERAL OPTOKINETIC STIMULI (I.E., STIMULI ROTATING IN OPPOSITE DIRECTIONS) HAS SHOWN THAT EXOCENTRIC ORIENTATION DEPENDS ON THE PERIPHERAL STIMULUS WHEREAS OPTOKINETIC NYSTAGMUS AND EGOCENTRIC MOTION PERCEPTION RELY ON THE CENTER OF THE VISUAL FIELD.

BRANDT, T.H., DICHGANS, J.M., AND BUCHELE, W., 'MOTION HABITUATION: INVERTED SELF-MOTION PERCEPTION AND OPTOKINETIC AFTER-NYSTAGMUS', EXP BRAIN RES 21 (1974) 337-352.

* ABSTRACT *

THE 'ECCULOMOTOR AND PERCEPTUAL AFTER-EFFECTS' (AE) OF OPTOKINETIC MOTION STIMULATION AS WELL AS THE ADAPTIVE CHANGES DURING STIMULATION WERE STUDIED. THE INTENSITY AND DURATION OF OPTOKINETIC AFTER-NYSTAGMUS (OKAN) AND SELF-MOTION AFTER-SENSATION (CV) ARE A FUNCTION OF STIMULUS DURATION. THE DIRECTION IS A RESULT OF TWO COMPETING PROCESSES: POSITIVE TONUS CONTINUING THE ACTUAL RESPONSE TO THE STIMULUS AND NEGATIVE TONUS CAUSING A REVERSAL IN DIRECTION. POSITIVE AE'S INCREASE WITH STIMULUS DURATIONS UP TO 1 MIN; THE NEGATIVE AE'S INCREASE UP TO THE LONGEST STIMULUS DURATION TESTED (15 MIN) AND BY ANTAGONIZING THE POSITIVE AE'S SHORTEN THEIR DURATION ONCE STIMULUS DURATION EXCEEDS 3 MIN. NEGATIVE AE'S ARE INTERPRETED AS THE CONSEQUENCE OF A CENTRAL (COUNTER-REGULATION TO THE ACTUAL STIMULUS EFFECTS: 'MOTION HABITUATION'.

DURING PROLONGED STIMULATION, MOTION HABITUATION CAUSES AN APPARENT DECREASE IN PERCEIVED VELOCITY AND MAY RESULT IN THE SENSATION OF PERIODIC REVERSALS OF THE DIRECTION OF PERCEIVED SELF-MOTION, CONCURRENT WITH A SHIFT IN AVERAGE EYE POSITION TOWARDS THE DIRECTION OF THE APPARENT REVERSAL OF SELF-MOTION, I.E. THE NYSTAGMIC 'SCHLAGFELD' REVERSES FROM THE NORMAL RAPID-PHASE-SIDE TO THE SLOW-PHASE AS DOES ALSO THE CV.

ECCULOMOTOR AND PERCEPTUAL AE'S SIMILARLY DEPEND ON STIMULUS QUALITIES (E.G. DURATION, AREA OF THE MOVING STIMULUS AND ITS LOCATION IN THE VISUAL FIELD). IT IS ARGUED THAT POSITIVE AE'S ARE DUE TO AN IMPALANCE IN THE VESTIBULAR NUCLEI BY THE STIMULUS, AND IT IS HYPOTHEZISED THAT MOTION HABITUATION ACTS UPON THE VESTIBULAR NUCLEI.

BRANDT, T.H., WIST, E.R., AND DICHGANS, J.M., 'FOREGROUND AND BACKGROUND IN DYNAMIC SPATIAL ORIENTATION', PERCEPTION AND PSYCHOPHYSICS, VOL. 17, (5), (1975), 497-503.

* ABSTRACT *

THE DEPENDENCY OF VISUALLY INDUCED SELF-MOTION SENSATION UPON THE DENSITY OF MOVING CONTRASTS AS WELL AS UPON ADDITIONAL STATIONARY CONTRASTS IN THE FOREGROUND OR BACKGROUND WAS INVESTIGATED. USING TWO DIFFERENT OPTOKINETIC STIMULI, A DISK ROTATING IN THE FRONTOPARALLEL PLANE, AND THE PROJECTION OF HORIZONTALLY MOVING STRIPES ONTO A CYLINDRICAL SCREEN, IT WAS FOUND THAT: (1) VISUALLY INDUCED SELF-MOTION DEPENDS UPON THE DENSITY OF MOVING CONTRASTS RANDOMLY DISTRIBUTED WITHIN THE VISUAL FIELD AND, WITH A SINGLE CONTRAST AREA OF 1/4%, IS SATURATED WHEN ABOUT 30% OF THE VISUAL FIELD IS MOVING; (2) ADDITIONAL STATIONARY CONTRASTS

TRAITS INHIBIT VISUALLY INDUCED SELF-MOTION, PROPORTIONAL TO THEIR DENSITY; AND (3) THE LOCATION IN DEPTH OF THE STATIONARY CONTRASTS HAS A SIGNIFICANT EFFECT UPON THIS INHIBITION. THEIR EFFECT IS CONSIDERABLE WHEN LOCATED IN THE BACKGROUND OF THE MOVING STIMULI BUT WEAK WHEN APPEARING IN THE FOREGROUND. IT IS CONCLUDED THAT DYNAMIC VISUAL SPATIAL ORIENTATION RELIES MAINLY ON INFORMATION FROM THE SEEN PERIPHERY, BOTH RETINAL AND DEPTH.

 PRAY, R.S. INITIAL OPERATING EXPERIENCE WITH AN AIRCRAFT SIMULATOR HAVING EXTENSIVE LATERAL MOTION. AMES RESEARCH CENTER, MOFFETT FIELD, CA 'NASA TECHNICAL MEMORANDUM' X-62, 155 MAY, 1972.

* ABSTRACT *
 LATE IN 1969, A NEW RESEARCH FLIGHT SIMULATION FACILITY, TERMED THE FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT, WAS PUT INTO OPERATION AT AMES RESEARCH CENTER. THIS FACILITY FEATURES AN EXTENSIVE COCKPIT MOTION SYSTEM, EMPHASIZING LATERAL MOTION FOR THE SIMULATION OF LATERAL-DIRECTIONAL CONTROL TASKS. THIS PAPER DESCRIBES BRIEFLY THE MOTION CAPABILITIES OF THE SIMULATOR AND DESCRIBES IN DETAIL THE LOGIC WITH WHICH THE MOTION DRIVES ARE CONTROLLED TO PROVIDE THE MOST EFFECTIVE APPROXIMATIONS OF THE MOTIONS OF FLIGHT. PRELIMINARY ASSESSMENTS OF THE EFFECTIVENESS OF THESE MOTIONS, IN THE SIMULATION OF LARGE TRANSPORT AIRCRAFT, ARE DISCUSSED.

 PRAY, R.S. 'A STUDY OF VERTICAL MOTION REQUIREMENTS FOR LANDING SIMULATION'. 'HUMAN FACTORS', 1973, 15, 561-568.
 ALSO NASA TECH. MEMO TM X-62,236 AUGUST 1972

* ABSTRACT *
 TESTS WERE CONDUCTED TO DETERMINE THE SIGNIFICANCE OF VERTICAL ACCELERATION CUES IN THE SIMULATION OF THE VISUAL APPROACH AND LANDING MANEUVER. LANDING PERFORMANCE MEASURES WERE OBTAINED FOR FOUR SUBJECT PILOTS OPERATING A VISUAL LANDING SIMULATION MECHANIZED IN THE AMES HEIGHT CONTROL TEST APPARATUS, A DEVICE THAT PROVIDES UP TO $\pm 80 = 40$ FT OF VERTICAL MOTION. TEST RESULTS INDICATE THAT VERTICAL MOTION CUES ARE UTILIZED IN THE LANDING TASK, AND THAT THEY ARE PARTICULARLY IMPORTANT IN THE SIMULATION OF AIRCRAFT WITH MARGINAL LONGITUDINAL HANDLING QUALITIES. TO ASSURE VERTICAL MOTION CUES OF THE DESIRED FIDELITY IN THE LANDING TASK, IT APPEARS THAT A SIMULATOR MUST HAVE EXCURSION CAPABILITIES OF AT LEAST $\pm 80 = 20$ FT.

 PRAY, R.S., DRINKWATER, F.J., AND EMMETT, B.F. THE INFLUENCE OF MOTION ON THE EFFECTIVENESS OF FLIGHT SIMULATORS IN TRAINING

MANEUVERS. 'NASA AIRCRAFT SAFETY AND OPERATING PROBLEMS CONFERENCE', NASA SP-270, MAY 1971. U77-785F

* ABSTRACT *

THE USE OF A NEW RESEARCH FLIGHT SIMULATOR HAS DEMONSTRATED THE VALUE OF LATERAL MOTION CUES IN THE SIMULATION OF MANEUVERS REQUIRED IN THE TRAINING OF AIR-TRANSPORT PILOTS. THE AVAILABILITY OF VERY EXTENSIVE LATERAL MOTION HAS PROVIDED THE OPPORTUNITY TO FORM A TENTATIVE DEFINITION OF THE MINIMUM LATERAL MOTION REQUIRED TO PRODUCE THE DESIRED SIMULATION FIDELITY. THE LESS EXTENSIVE VERTICAL MOTION CAPABILITIES OF THE SIMULATOR PROVIDED USEFUL CUES BUT DID NOT MARKEDLY REDUCE THE LONG-STANDING PROBLEM OF ACCURATELY SIMULATING THE FLARE AND TOUCHDOWN PORTION OF THE LANDING MANEUVER. THE OVERALL EFFECTIVENESS OF THE SIMULATOR IN TAKEOFF AND LANDING MANEUVERS INVOLVING LATERAL-DIRECTIONAL CONTROL PROBLEMS SUGGESTS THAT THE SCOPE OF SIMULATOR TRAINING TASKS CAN BE EXPANDED BEYOND THOSE CURRENTLY PERFORMED IN FLIGHT AND SIMULATORS.

BREAM, J.R. AN ANNOTATED BIBLIOGRAPHY ON THE BEHAVIORAL ASPECTS OF FLIGHT SIMULATION. AIR COMMAND AND STAFF COLLEGE, AIR UNIVERSITY, MAXWELL AIR FORCE BASE, AL, REPORT 0290-77, MAY 1977.

* ABSTRACT *

THIS ANNOTATED BIBLIOGRAPHY LISTS, DESCRIBES AND EVALUATES 107 REPORTS. EMPHASIS IS ON SIMULATOR/TRAINING DEVICES FOR AIR CREW TRAINING, VISUAL SYSTEMS, MOTION SYSTEMS, TRANSFER OF TRAINING, PERFORMANCE AND SIMULATOR FIDELITY. A DISCUSSION OF THESE ASPECTS IS ALSO PROVIDED AS IS A SUBJECT/KEY WORD INDEX.

BRUL, F.T.
A SIMULATOR STUDY OF TILT-WING HANDLING QUALITIES.
GRUMMAN AIRCRAFT ENGINEERING CORPORATION, BETHPAGE, N.Y.
GRUMMAN RESEARCH DEPARTMENT REPORT
OF-162, MAR. 1963. (ALSO IN AIAA SIMULATION FOR AEROSPACE FLIGHT CONFERENCE, AUG. 26-28, 1963, COLUMBUS, OHIO)

* ABSTRACT *

AN EXPERIMENTAL INVESTIGATION WAS PERFORMED TO STUDY HANDLING QUALITIES OF TILT-WING TYPE VTOL AIRCRAFT. A FLIGHT SIMULATOR CONSISTING OF A COCKPIT FREE TO PITCH AND ROLL, AND AN OPTICAL DISPLAY SYSTEM PROVIDING A VISUAL ILLUSION OF MOTION IN THE REMAINING FOUR DEGREES OF FREEDOM WAS EMPLOYED IN THIS PROGRAM. QUALIFIED PILOTS OPERATED BOTH A LONGITUDINAL THREE DEGREE OF FREEDOM AND A SIX DEGREE OF FREEDOM MECHANIZATION OF A SIMULATED 15,000 POUND TILT-WING TYPE VTOL AIRPLANE. FOUR PILOTS EVALUATED OVER 350 CONFIGURATIONS AT HOVER AND DURING

CONTINUOUS TRANSITIONS IN CALM AIR AND UNDER VISUAL FLYING CONDITIONS.

CONTROL SENSITIVITY AND RATE DAMPING REQUIREMENTS ABOUT EACH AXIS AT HOVER WERE INVESTIGATED RELATIVE TO THE PERFORMANCE OF MANEUVERING TASKS THAT REQUIRE, IN GENERAL, MORE POSITIVE CONTROL APPLICATIONS THAN 'TRIMMING' AND MORE FINELY COORDINATED MULTIPLE CONTROL UTILIZATION THAN SINGLE DEGREE OF FREEDOM 'MOVE AND STOP' MANEUVERS. THAT HANDLING QUALITIES REQUIREMENTS DEPEND UPON THE MANEUVER IN WHICH THEY ARE MEASURED AND THE DEGREE OF SIMULATOR SOPHISTICATION IS CLEARLY SUGGESTED BY COMPARING THE RESULTS OF THE PRESENT STUDY WITH PUBLISHED NASA DATA REPRESENTING THE EXTREMES IN THE 'MANEUVER SPECTRUM.'

CONTROL RESPONSE-TIME CHARACTERISTICS, AS WELL AS CONTROL, AERODYNAMIC RATE, AND GYROSCOPIC COUPLING EFFECTS WERE ALSO INVESTIGATED AT HOVER. THE RESULTS OF THE CONTROL RESPONSE-TIME VARIATIONS ARE MOST INTERESTING, FOR THEY SUGGEST THAT THE CRITERION UPON WHICH PRESENT HELICOPTER SPECIFICATIONS ARE BASED (I.E., TIME TO REACH PROPER DIRECTION OF ACCELERATION) IS INADEQUATE.

TRANSITION HANDLING QUALITIES ARE DISCUSSED PRIMARILY WITH REGARD TO WHETHER SATISFACTION OF HOVER DERIVED CRITERIA IS SUFFICIENT TO ENSURE GOOD HANDLING QUALITIES FOR THE PERFORMANCE OF THE TRANSITION MANEUVER. THAT IS, DO HANDLING QUALITIES REMAIN ACCEPTABLE DURING A TRANSITION MANEUVER IF RATE DAMPING AND CONTROL SENSITIVITY, WHICH ARE ALLOWED TO VARY IN TYPICAL FASHION, ALWAYS REMAIN WITHIN THE ACCEPTABLE HOVER BOUNDARIES. SEVERAL PARAMETERS UNIQUE TO VTOL DESIGNS (E.G., WING TILT RATE) ARE ALSO DISCUSSED IN LIGHT OF THEIR EFFECTS ON TRANSITION HANDLING QUALITIES.

THE CRITICAL RESULT HERE IS THAT HANDLING QUALITIES CRITERIA DERIVED FROM HOVER OR STEADY FLIGHT EXPERIMENTATION CANNOT, IN GENERAL, BE STRETCHED TO INCLUDE NONSTEADY (E.G., TRANSITION) FLIGHT.

BRELL, F.T. A SIMULATOR STUDY OF LOW-SPEED VTOL HANDLING QUALITIES IN TURBULENCE. GRUMMAN AIRCRAFT ENGINEERING CORP. RE 238, NAA 65-0512 FEBRUARY 1966.

* ABSTRACT *

AN EXPERIMENTAL STUDY WAS PERFORMED TO DETERMINE, FROM THE PILOT'S POINT OF VIEW, THE EFFECTS OF CERTAIN STABILITY DERIVATIVES, ATMOSPHERIC TURBULENCE, AND CONTROL POWER ON THE HANDLING QUALITIES OF VTOL CRAFT. USING A FLIGHT SIMULATOR, QUALIFIED PILOTS EVALUATED OVER 450 CONFIGURATIONS IN THE TASK OF MOVING THE CRAFT FROM ONE HOVER SPOT TO ANOTHER. THE SIMULATOR CONSISTED OF A COCKPIT PROVIDING MOTION IN ROLL AND

PITCH AND AN OPTICAL DISPLAY SYSTEM PROVIDING AN ILLUSION OF MOTION IN THE REMAINING FOUR DEGREES OF FREEDOM.

THE PRIMARY CONCLUSION DRAWN FROM THE STUDY IS THAT SPEED STABILITY, EITHER LATERAL OR LONGITUDINAL, STRONGLY INFLUENCES A HAVINGING VEHICLE'S CONTROL POWER AND ANGULAR RATE DAMPING REQUIREMENTS. FURTHERMORE, LATERAL AND LONGITUDINAL REQUIREMENTS ARE FOUND TO BE SIMILAR, WHEN THE EFFECTS OF SPEED STABILITY ARE TAKEN INTO ACCOUNT.

BROWN, A.C.
SENIOR SCIENTIFIC OFFICER, BLIND LANDING EXPERIMENTAL UNIT,
ROYAL AIRCRAFT ESTABLISHMENT, BEDFORD, ENGLAND 70 - 344.
AN EXAMINATION OF SIMULATOR LANDING PROBLEMS. AIAA VISUAL AND
MOTION SIMULATION TECHNOLOGY CONFERENCE MARCH 16-18, 1970 (CAPE)

* ABSTRACT *

THE LANDING PERFORMANCE OF THE BLEU STATIC COCKPIT SIMULATOR IS COMPARED WITH FLIGHT DATA FOR NIGHT CONDITIONS IN CLEAR AND LIMITED VISIBILITY. ONLY THE INSTANT OF TOUCHDOWN IS CONSIDERED FOR THE SIX PARAMETERS DESCENT RATE, LONGITUDINAL POSITION, LATERAL RATE, BANK ANGLE, LATERAL POSITION, AND PITCH ANGLE. SINCE THE FIRST FOUR SHOWED SIGNIFICANT DIFFERENCES, FLIGHT AND SIMULATOR EXPERIMENTS WERE MADE TO DETERMINE WHETHER THESE COULD BE CAUSED BY INHERENT VISUAL DISPLAY LIMITATIONS. RESTRICTED PERIPHERAL VISION, MONOCULAR VISION, AND PILOT-DISPLAY VIEWING DISTANCE WERE EXAMINED BUT NO SIGNIFICANT EFFECTS WERE FOUND THAT COULD EXPLAIN THE SIMULATOR RESULTS. FROM THIS AND ADDITIONAL DATA, IT IS CONCLUDED THAT SOME FORM OF COCKPIT MOTION MUST BE NECESSARY TO ACHIEVE REALISTIC LANDING PERFORMANCES. THE PRESENT SIMULATOR DEVELOPMENT PROGRAM IS DESIGNED TO PRODUCE AN IMPROVED NIGHT DISPLAY THAT IS COMPATIBLE WITH COCKPIT MOTION USING DIGITAL TECHNIQUES FOR THE APPROACH AND RUNWAY LIGHTING PATTERN GENERATION.

BROWN, B.P. AND JOHNSON, H.J. MOVING COCKPIT SIMULATOR INVESTIGATION OF THE MINIMUM TOLERABLE LONGITUDINAL MANEUVERING STABILITY, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TECHNICAL NOTE D-26, LANGLEY RESEARCH CENTER, LANGLEY FIELD, VIRGINIA, 1959.

* ABSTRACT *

TESTS HAVE BEEN MADE ON THE NASA NORMAL ACCELERATION AND PITCH (NAP) SIMULATOR UTILIZING A CLOSE FORMATION FLYING TASK FOR THE PURPOSE OF STUDYING THE EFFECTS ON CONTROLLABILITY OF VARIOUS AMOUNTS OF AIRCRAFT STABILITY AND VARIOUS AMOUNTS OF STICK FORCE AND POSITION GRADIENTS. THE SIMULATOR REPRESENTS ONLY THE COCKPIT PORTION OF AN AIRCRAFT OR SPACE VEHICLE AND IT IS

ABLE TO ROTATE IN PITCH AND TO MOVE VERTICALLY. THE MOTIONS PROVIDED BY THE SIMULATOR ARE THOSE ASSOCIATED WITH THE SHORT PERIOD LONGITUDINAL MODE.

THE RESULTS FROM THESE TESTS INDICATE THAT THE MANEUVER NEUTRAL POINT IS A REASONABLE REARWARD LIMIT FOR THE AIRCRAFT CENTER OF GRAVITY WITH RESPECT TO CONTROLLABILITY. BEYOND THIS POINT CONTROL IS EXTREMELY UNCERTAIN. THE BEST PERFORMANCES IN THE SIMULATED FORMATION FLYING TASK WERE OBTAINED WITH FORCE GRADIENTS MANY TIMES LARGER THAN THOSE SPECIFIED FOR GROSS MANEUVERING FOR FIGHTER-TYPE AIRPLANES IN PRESENT-DAY FLYING QUALITIES REQUIREMENTS. THIS RESULT INDICATES THE IMPORTANCE OF FORCE GRADIENT TO PRECISION CONTROL. THESE FORCES WOULD, HOWEVER, BE EXCESSIVE FOR MANEUVERS REQUIRING STEADY ACCELERATIONS EXCEPT WHEN THE CENTER OF GRAVITY IS AT OR VERY NEAR TO THE MANEUVER POINT. FOR THE CASES WITH SOME AMOUNT OF STICK FORCE GRADIENT, PERFORMANCE IMPROVED WHEN THE STICK POSITION GRADIENT WAS INCREASED FROM 1.13 DEGREES TO 2.0 DEGREES OF STICK ROTATION PER DEGREE OF TAIL DEFLECTION. A FURTHER INCREASE OF 4.5 DEGREES SHOWED NO IMPROVEMENT FOR THESE CASES. FOR THE CASES WITH ZERO FORCES, EACH INCREASE IN POSITION GRADIENT RESULTED IN INCREASED PERFORMANCE. THE PILOTS FELT, HOWEVER, THAT THE EFFECT OF POSITION GRADIENT WAS SMALL. REDUCTION IN AIRCRAFT DAMPING RESULTED IN SOMEWHAT LOWER PERFORMANCE; HOWEVER, THIS EFFECT WAS NOT CONSIDERED TO BE SERIOUS IN THIS INVESTIGATION. THE DIFFERENCES IN PERFORMANCE AS MEASURED WITH AND WITHOUT THE PITCHING MOTION WERE VERY SMALL FOR ONE PILOT AND NEGLIGIBLE FOR THE OTHER. THEREFORE, THE PITCHING MOTION CUES WERE NOT CONSIDERED TO BE OF IMPORTANCE TO PERFORMANCE IN CLOSE-FORMATION FLYING.

BROWN, B.F., JOHNSON, H.I., AND MUNGALL, R.G. (1960); 'SIMULATOR MOTION EFFECTS ON A PILOT'S ABILITY TO PERFORM A PRECISE LONGITUDINAL FLYING TASK'; NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, NASA TN-D-367.

* ABSTRACT *

TASK CONSISTS OF FOLLOWING A MARKER WHICH WOULD BE CONTROLLED FROM THE COCKPIT INTERIOR. THIS TASK RESEMBLED CLOSE FORMATION FLYING OR REFUELLING IN A HIGH-SPEED FIGHTER. TWO SUBJECTS PERFORMED THE TASK ALTERNATELY IN A STATIC COCKPIT AND IN A DYNAMIC COCKPIT. RESULTS AND PILOT OPINION INDICATED PREFERENCE FOR DYNAMIC COCKPIT. CONTROL CORRECTIONS IN WRONG DIRECTION WERE OFTEN MADE IN STATIC COCKPIT.

BROWN, J.L. ACCELERATION AND MOTOR PERFORMANCE, 'HUMAN FACTORS' VOL. 2, PP. 175-185, NOVEMBER 1960.

* ABSTRACT *

EXPERIMENTS CONCERNING THE EFFECTS OF ACCELERATION ON MOTOR PERFORMANCE ARE DISCUSSED IN A SEQUENCE WHICH ILLUSTRATES THE EVALUATION OF RESEARCH TECHNIQUES IN RECENT YEARS. IN THE SIMPLEST OF THESE TECHNIQUES, PERFORMANCE IS EVALUATED DURING OR IMMEDIATELY FOLLOWING EXPOSURE TO PRE-PROGRAMMED ACCELERATION TIME HISTORIES. A MORE COMPLEX TECHNIQUE INVOLVES THE STUDY OF INTERACTION OF SUBJECT PERFORMANCE WITH THE PATTERN OF ACCELERATION EXPERIENCED. ACCELERATIONS ARE ACTUALLY CONTROLLED BY SUBJECT PERFORMANCE BY MEANS OF AN ANALOG COMPUTER CONTROL SYSTEM. CERTAIN LIMITATIONS OF CENTRIFUGE SIMULATIONS ARE DISCUSSED.

BROWN, C. L.
VISUAL AND MOTION SIMULATION TECHNIQUES.
XEROX, LINK GROUP LIBRARY.
ACCESSION NO. 1651.
1965.

* ABSTRACT *

IF THE MOTIONS OF FLIGHT MAY GIVE RISE TO FALSE PERCEPTIONS, THEN IN THEIR ABSENCE A PILOT MIGHT BE EXPECTED TO PERFORM BETTER THAN IN THE REAL LIFE SITUATION. ~~THUS~~ IF MOTION IS ADDED, A MORE PESSIMISTIC BUT MORE REALISTIC ASSESSMENT OF PILOT PERFORMANCE MAY RESULT.

THE MOST FREQUENTLY HEARD JUSTIFICATION FOR THE ADDITION OF MOTION CUES IS THAT THEY AFFORD AN INCREASE IN REALISM. WHEN THIS JUSTIFICATION IS APPLIED TO SITUATIONS IN WHICH MOTIONS ARE NOT EXTREME IT MUST BE EXAMINED VERY CAREFULLY. THERE IS VERY LITTLE SATISFACTORY EVIDENCE TO VALIDATE THE ASSUMPTION THAT THE ADDITION OF MOTION CUES IN A LABORATORY SIMULATOR ACTUALLY INCREASES REALISM. THE VALUE OF A SIMULATOR MUST BE MEASURED IN TERMS OF HOW WELL IT IMPROVES OUR ABILITY TO PREDICT THE WAY A PILOT WILL DO HIS JOB IN THE SITUATION WHICH IS BEING SIMULATED.

THE ARTICLE IS A GENERAL DISCUSSION OF THE USE OF THE JOHNSVILLE CENTRIFUGE FOR SIMULATING THE X-15 AND SPACE VEHICLES, THE PROBLEMS ENCOUNTERED IN PROVIDING REALISTIC LINEAR AND ANGULAR ACCELERATIONS AND SOME OF THE RESULTS OBTAINED COMPARED TO PILOTS' PERFORMANCE IN ACTUAL AIRCRAFT OTHER THAN X-15 AND SPACE VEHICLES.

BROWN, C. L. VISUAL ELEMENTS IN FLIGHT SIMULATION. UNIVERSITY OF ROCHESTER, CENTER FOR VISUAL SCIENCE, ROCHESTER, NEW YORK. IN AVIATION SPACE AND ENVIRONMENTAL MEDICINE, VOLUME 47, NUMBER 9, SEPTEMBER 1976 PAGES 913-924.

* ABSTRACT *

FLIGHT SIMULATORS HAVE BEEN IN USE FOR MANY YEARS AND THEIR VALUE HAS BEEN AMPLY PROVEN. MANY OF TODAY'S SIMULATORS ARE VERY EXPENSIVE, BUT THEY CAN PAY FOR THEMSELVES BY DECREASING COST AND INCREASING SAFETY IN TRAINING PILOTS TO FLY COMPLEX AND EXPENSIVE MODERN AIRCRAFT. SOME ASPECTS OF AIRCRAFT CONTROL DEPEND ON AN EXTERIOR VIEW FROM THE AIRCRAFT TO THE OUTSIDE VISUAL WORLD. TRAINING IN THESE ASPECTS OF FLIGHT IN A SIMULATOR REQUIRES SIMULATION OF THE VISUAL WORLD TO THE EXTENT THAT CUES DERIVED FROM IT NEED TO BE EMPLOYED BY THE PILOT. A NUMBER OF MANEUVERS CANNOT BE PERFORMED WITHOUT DIRECT VISUAL CONTACT UNDER NORMAL CIRCUMSTANCES IN COMMERCIAL AS WELL AS IN MILITARY AVIATION. THE IMPORTANCE OF INCLUDING A SIMULATION OF THE EXTERNAL WORLD IS NOW ACKNOWLEDGED. UNFORTUNATELY, THERE IS CURRENTLY NO SOLID SCIENTIFIC BASIS FOR CATALOGING VISUAL CUES WITH RESPECT TO THEIR IMPORTANCE IN AIRCRAFT CONTROL. THIS REPORT RECOMMENDS RESEARCH TOPICS, TECHNIQUES AND STRATEGIES THAT SHOULD RECEIVE MORE ATTENTION. IT ALSO HAS A SECTION ON MOTION SIMULATION.

RODAN, J.L. AND BURKE, R.E. THE EFFECT OF POSITIVE ACCELERATION ON VISUAL REACTION TIME. JOURNAL OF AVIATION MEDICINE, VOLUME 29, PAGES 48-58, JANUARY 1958.

* ABSTRACT *

IN THE EXPERIMENT REPORTED HEREIN, TWO WIDELY DIFFERENT TEST LIGHT LUMINANCES WERE USED TO INVESTIGATE THE RELATIONS OF BOTH TOLERANCE AND REACTION TIME TO TEST LIGHT LUMINANCE UNDER POSITIVE ACCELERATION. TWO TEST LIGHT POSITIONS, ONE IN THE FAR PERIPHERY AND ONE IN THE NEAR PERIPHERY, WERE EMPLOYED TO DETERMINE WHETHER ACCELERATION TOLERANCE MIGHT BE LOWER AND REACTION TIME MORE PROLONGED FOR TEST LIGHTS AT GREATER ANGULAR DISPLACEMENTS FROM THE FOVEA.

IT MAY BE CONCLUDED THAT VISUAL REACTION TIME DOES SHOW SOME RELATION TO THE LEVEL OF POSITIVE ACCELERATION. THE VARIABILITY OF REACTION TIME IS SUCH HOWEVER THAT INDIVIDUAL MEASURES DO NOT AFFORD A RELIABLE, DIRECT, QUANTITATIVE INDEX OF THE PHYSIOLOGIC EFFECTS OF POSITIVE ACCELERATION.

IT IS POSSIBLE ONLY TO SPECULATE CONCERNING THE SIGNIFICANCE OF SUBJECTS' REPORTS OF THE FAILURE OF FORM VISION WITH THE HIGHER LUMINANCE TEST LIGHT. NOELL (1951) HAS SUGGESTED THAT FUNCTIONS WHICH UNDERLIE FACILITATION AND INHIBITION IN THE MAMMALIAN VISUAL SYSTEM MAY BE THE FIRST TO SHOW EFFECTS OF ANOXIA. IT SEEMS LIKELY THAT SUCH FUNCTIONS ARE OF IMPORTANCE IN FORM DISCRIMINATION. THE SUBJECTIVE REPORTS OF DIMMING OF PERIPHERAL LIGHTS AND TUNNEL VISION DURING POSITIVE ACCELERATION MAY ACTUALLY REPRESENT A BREAKDOWN OF FORM DISCRIMINATION WHICH FIRST OCCURS IN THE PERIPHERAL RETINA AND THEN SPREADS TO THE FOVEA. THE SIMPLE DETECTION OF A TEST

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LIGHT FLASH MAY BE POSSIBLE RIGHT UP TO THE POINT OF UNCONSCIOUSNESS IF THE VISUAL FIELD IS SUFFICIENTLY DARKENED, IF A TEST LIGHT OF SUFFICIENTLY HIGH LUMINANCE IS EMPLOYED AND IF SUBJECTS ARE TRAINED TO RESPOND TO ANY CHANGE IN DIFFUSE LIGHT WHICH IS APPARENT IN THE VISUAL FIELD.

BROWN, C.L. AND COLLINS, C.C. 'AIR-TO-AIR TRACKING DURING CLOSED-LOOP CENTRIFUGE OPERATION', U.S. NADC AVIATION MEDICAL ACCELERATION LABORATORY, NADC/MA-5803, MARCH 1958. ALSO J. AVIAT. MED., 29: 794-804.

* ABSTRACT *

TWO PILOTS AND THREE NON-PILOTS PERFORMED SIMULATED CHASE FLIGHT TASK ON STATIC AND DYNAMIC CENTRIFUGE. PITCH (AND, INSIGNIFICANTLY, ROLL) PERFORMANCE WAS BETTER IN THE STATIC SIMULATION, WHILE LATERAL CO-ORDINATION (CONTROL OF SWAY) WAS BETTER IN THE DYNAMIC SIMULATION. HENCE COCKPIT ACCELERATIONS ARE IMPORTANT SINCE THEY CAN EITHER INTERFERE WITH PERFORMANCE OR PROVIDE USEFUL INFORMATION.

BROWN, C. L., ELLIS, W. H. B., WEBB, M. G., AND GRAY R. F. 'THE EFFECT OF SIMULATED CATAPULT LAUNCHING ON PILOT PERFORMANCE.' U. S. NAVAL AIR DEVELOPMENT CENTER, AVIATION MEDICAL ACCELERATION LABORATORY, REPORT NO. NADC-MA-5719, DECEMBER 31, 1957.

* ABSTRACT *

FOUR SUBJECTS WERE EXPOSED TO ACCELERATION PATTERNS WHICH SIMULATED THE ACCELERATIONS OF CATAPULT LAUNCHINGS UP TO 11 G. SUBJECTS WERE TRAINED IN A TASK WHICH REQUIRED STABILIZATION, BY MANIPULATION OF A CONTROL STICK, OF DISTURBANCES OF A STANDARD PITCH AND ROLL INDICATOR. SCORES FOR PERFORMANCE WERE OBTAINED DURING A CONTROL PERIOD PRIOR TO ACCELERATION EXPOSURE AND IMMEDIATELY FOLLOWING EXPOSURE. PERFORMANCE IMMEDIATELY FOLLOWING EXPOSURE SHOWED NO DECREMENT AT ANY LEVEL OF ACCELERATION WHEN COMPARED WITH PERFORMANCE PRIOR TO EXPOSURE. SOME DISCOMFORT AT THE HIGHER LEVELS OF ACCELERATION WAS ATTRIBUTED TO A NEGATIVE COMPONENT OF ACCELERATION ON THE SUBJECT WHICH WAS PROPORTIONAL TO THE SINE OF THE ANGLE FORMED BY THE SEAT-BACK WITH THE VERTICAL. (ALTHAN)

BROWN, C.L., KUEHNEL, H., NICHOLSON, F. AND FUTTERWEIT, A. 'INVALIDITY OF THE CENTRIFUGE AS A FLIGHT SIMULATOR'. U.S. NAVAL

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AIR DEVELOPMENT CENTER, AVIATION MEDICAL ACCELERATION LABORATORY REPORT NO. NADC-MA-6C-16, 1960.

* ABSTRACT *

FOUR PILOTS, TWO NON-PILOTS FLEW PITCH AND ROLL TASK ON CRT DISPLAY IN AIRCRAFT, AND IN STATIC AND DYNAMIC CENTRIFUGE SIMULATION. PERFORMANCE IN DYNAMIC CENTRIFUGE INFERIOR TO THAT IN STATIC; CONSIDERED DUE TO SPURIOUS ANGULAR ACCELERATIONS NEEDED TO CHANGE LINEAR G MAGNITUDE OR VECTOR. PILOTS PERFORMED CONSISTENTLY BETTER IN AIRCRAFT; A NON-PILOT ACHIEVED BEST PERFORMANCE ON CENTRIFUGE. OBSERVATION THAT PILOTS, USED TO REAL MOTION CLUES, MAY FIND IT MORE DIFFICULT TO LEARN TO 'FLY' CENTRIFUGE THAN DO NAIVE NON-PILOTS.

BROWN, J.L., KUEHNEL, H., NICHOLSON, F. AND FETTERWEIT, A., 'A COMPARISON OF TRACKING PERFORMANCE IN THE TV-2 AIRCRAFT AND THE ACL COMPUTER/ANAL HUMAN CENTRIFUGE SIMULATION OF THIS AIRCRAFT'. NADC MA-6C16/NADC-AC-6008, JOHNSVILLE, PENN., AD 250 129, NOV. 1960.

* ABSTRACT *

A TRACKING TASK WAS PERFORMED BY EACH OF SIX SUBJECTS IN A TV-2 AIRCRAFT, IN A STATIC SIMULATION OF THE AIRCRAFT AND IN EACH OF TWO CENTRIFUGE MODES OF SIMULATION WHICH PROVIDED ACCELERATION FORCES SIMILAR TO THOSE ENCOUNTERED IN THE AIRCRAFT. CENTRIFUGE ACCELERATIONS WERE CONTROLLED BY PILOT PERFORMANCE IN THE SIMULATION. A PRELIMINARY ANALYSIS OF TRACKING PERFORMANCE WAS CONDUCTED BASED ON ABSOLUTE ERROR. IN ORDER TO PERFORM THIS ANALYSIS IT WAS NECESSARY TO FILTER OUT LOW FREQUENCY BIASES WHICH AFFECTED DATA IN THE AIRCRAFT BUT NOT IN THE CENTRIFUGE. CONCLUSIONS FROM THE ANALYSIS MUST BE QUALIFIED ACCORDINGLY. TRACKING PERFORMANCE ON THE CENTRIFUGE WAS INFERIOR TO PERFORMANCE UNDER STATIC CONDITIONS. IN THE CASE OF FOUR SUBJECTS WHO ARE QUALIFIED PILOTS, PERFORMANCE IN THE AIRCRAFT WAS CONSISTENTLY SUPERIOR TO PERFORMANCE ON THE CENTRIFUGE AND FREQUENTLY SUPERIOR TO PERFORMANCE UNDER STATIC CONDITIONS. THE SUBJECT, A NON-PILOT, WHO HAD THE BEST PERFORMANCE ON THE CENTRIFUGE, HAD THE POORST PERFORMANCE IN THE AIRCRAFT. A SPECTRAL DENSITY ANALYSIS OF RESULTS OF THE EXPERIMENT WILL BE PRESENTED IN A SUBSEQUENT REPORT.

IN A QUESTIONNAIRE, ALL SUBJECTS RATED THE AIRCRAFT BEST IN TERMS OF CONTROL RESPONSE AND TENDED TO FAVOR THE AIRCRAFT OVER ANY OF THE SIMULATIONS. SUBJECTS REPORTED THAT ACCELERATIONS ON THE CENTRIFUGE WERE REALISTIC AS COMPARED TO ACCELERATIONS IN THE AIRCRAFT UNDER STEADY STATE CONDITIONS, BUT THEY SEEMED SOMEWHAT UNREALISTIC DURING RAPID TRANSITIONS FROM ONE ACCELERATION LEVEL TO ANOTHER. IT IS CONCLUDED THAT THE CENTRIFUGE IS BEST SUITED FOR THE SIMULATION OF LONG DURATION, HIGH MAGNITUDE ACCELERATIONS OF THE KIND WHICH WILL

BE ENCOUNTERED IN SPACE VEHICLES SUCH AS THE X-15 AND THE MERCURY CAPSULES. (AUTHORS)

BROWN, J. L. AND LECHNER, M. 'ACCELERATION AND HUMAN PERFORMANCE: A SURVEY OF RESEARCH'. AVIATION MEDICAL ACCELERATION LABORATORY, U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA. 'J. AVIATION MEDICINE', 1956, 27, 32-49.

* ABSTRACT *

THIS REPORT SUMMARIZES THE IMPORTANT RESEARCH WHICH HAS BEEN CONDUCTED TO DATE ON THE PROBLEM OF HUMAN PERFORMANCE UNDER ACCELERATION. THE MATERIAL HAS BEEN GROUPED ACCORDING TO FIVE MAJOR HEADINGS: THE SENSES, SIMPLE MOTOR BEHAVIOR, COMPLEX TASKS, COGNITIVE PROCESSES, AND PSYCHOLOGICAL EFFECTS. RESEARCH RELEVANT TO EACH OF THESE CLASSIFICATIONS IS REVIEWED, IMPORTANT QUESTIONS WHICH APPEAR TO REMAIN UNANSWERED ARE RAISED, AND SUGGESTIONS ARE MADE REGARDING DESIRABLE LINES FOR FUTURE RESEARCH. IT APPEARS THAT ONLY A VERY LIMITED AMOUNT OF RESEARCH HAS BEEN CONDUCTED RELATING TO ACTUAL PERFORMANCE SEQUENCES WHICH MAY BE REQUIRED OF PILOTS EXPOSED TO ACCELERATION.

BROWN, J. L., WOODWARD, L. K. AND PIDCOCK, G. B. 'OPTICAL SIGHTING: THE EFFECT OF POSITIVE ACCELERATION ON THE PILOTS HEAD POSITION.' U. S. NAVAL AIR DEVELOPMENT CENTER AVIATION MEDICAL ACCELERATION LABORATORY, REPORT NO. NACC-MA 5509 AUGUST 3, 1955.

* ABSTRACT *

WHILE USING AN OPTICAL GUN SIGHT, IT IS NECESSARY FOR A PILOT TO RESTRICT THE MOVEMENT OF HIS HEAD IN ORDER TO MAINTAIN VIEW OF THE SIGHTING RETICLE. THE ABILITY OF TWO HUMAN SUBJECTS TO MAINTAIN THEIR HEADS IN RELATIVELY FIXED POSITIONS WHILE EXPOSED TO POSITIVE ACCELERATION WAS INVESTIGATED ON THE CENTRIFUGE. IT WAS FOUND THAT HEAD POSITIONS RANGING FROM FORWARD INCLINATION OF THE HEAD TO SLIGHT ELEVATION AND BACKWARD TILTING OF THE HEAD COULD BE MAINTAINED AT ACCELERATIONS OF TO 5G. EVEN AT THE HIGHEST ACCELERATION, IT WAS POSSIBLE THOUGH WITH DIFFICULTY, TO MAKE CONTROLLED HEAD MOVEMENTS OPPOSITE TO THE DIRECTION OF THE FORCE OF ACCELERATION. HOWEVER, AT LEVELS OF ACCELERATION ABOVE 3G, BOTH SUBJECTS REPORTED THAT THE MAINTENANCE OF A FIXED HEAD POSITION, ESPECIALLY WITH THE HEAD INCLINED FORWARD, REQUIRED CONSIDERABLE EXERTION. IT WAS CONCLUDED THAT POSITIVE ACCELERATION OF THE MAGNITUDE ENCOUNTERED IN PRESENT DAY AIRCRAFT DOES NOT SERIOUSLY INTERFERE WITH THE MAINTENANCE OF HEAD POSITIONS REQUIRED FOR OPTICAL SIGHTING. (AUTHOR)

BROWN, R.F., RYAN, L.E., SCOTT, P.C. AND SMIDE, A.F. 'TRAINING EFFECTIVENESS EVALUATION OF DEVICE 2F87F, P-3C OPERATIONAL FLIGHT TRAINER'. TRAINING ANALYSIS AND EVALUATION GROUP, REPORT NO. 42, JANUARY 1977.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE TRAINING EFFECTIVENESS OF THE NEWLY INSTALLED DEVICE 2F87F OPERATIONAL FLIGHT TRAINER (OFT) AS A SUBSTITUTE FOR THE EARLIER GENERATION 2F69D OFT USED IN COMBINATION WITH THE P-3 AIRCRAFT IN TRAINING REPLACEMENT PATROL PLANE PILOTS. THIS STUDY PROVIDED THE OPPORTUNITY TO EVALUATE THE POTENTIAL OF A SOPHISTICATED STATE OF THE ART FLIGHT SIMULATOR CONCURRENT WITH ITS COMING ON LINE IN AN OPERATIONAL SETTING.

THE PERFORMANCE OF 27 RECENT UNDERGRADUATE PILOT TRAINING (UPT) GRADUATES TRAINED IN THE NEW OFT WAS COMPARED WITH THE PERFORMANCE OF UPT GRADUATES TRAINED UNDER THE PRE-2F87F CURRICULUM.

UTILIZING THE NEW 2F87F DEVICE IN THE ONGOING P-3 PROGRAM RESULTED IN:

A REDUCTION OF IN-FLIGHT TRAINING TIME REQUIRED FOR THE COMPLETION OF THE FAM/INST PHASE OF REPLACEMENT PILOT TRAINING.

A REDUCTION IN NUMBER OF PRACTICE LANDINGS IN THE AIRCRAFT FROM 52 TO 36 (31 PERCENT) AND

A REDUCTION IN AVERAGE TRAINING TIME DIFFERENCES BETWEEN FAST AND SLOW LEARNERS.

IT WAS CONCLUDED THAT:

THE AVERAGE NUMBER OF FLIGHTS REQUIRED TO QUALIFY PILOTS COULD BE REDUCED FROM SIX TO FOUR.

PRACTICE LANDINGS IN THE AIRCRAFT COULD BE REDUCED BY 16,

THE NARROW FIELD OF VIEW VISUAL SYSTEM ENHANCES THE TRAINING CAPABILITY OF THE NEW SIMULATOR AND APPEARS TO MEET THE REQUIREMENTS FOR MULTIENGINE TRAINING.

SUBSEQUENT PHASES OF STUDY ARE EXPECTED TO ADDRESS THE ISSUES:

THE EFFECT OF INCREASED SIMULATOR TRAINING

INCREASING THE PRECISION OF MEASURING PROFICIENCY

ASSESSMENT OF AN INTEGRATED SIMULATOR/FLIGHT REGIME

COMPARED TO A BLOCK TRAINING REGIME AS USED IN THIS STUDY.

AN EVALUATION OF THE CONTRIBUTION OF THE MOTION SYSTEM TO STUDENT PERFORMANCE AND POSSIBLE PHYSIOLOGICAL EFFECTS; I. E., MOTION SICKNESS.

DETERMINATION OF MEANINGFUL SUBSTITUTION RATIOS THROUGH COMPARISON OF A SIMULATOR-TRAINED GROUP WITH AN AIRCRAFT ONLY TRAINED GROUP, AND

ASSESSMENT OF THE EFFECT OF LOSS OF VISUAL SIMULATION ON TRAINEE SUBSTITUTION VALUES.

PRUGH, R.L. AND MCHUGH, J.G. FLIGHT SIMULATOR STUDY OF HUMAN PERFORMANCE DURING LOW-ALTITUDE, HIGH-SPEED FLIGHT. U.S. ARMY TRANSPORTATION RESEARCH COMMAND, FORT EUSTIS, VIRGINIA, (NORTH AMERICAN AVIATION, INC. COLUMBUS, OHIO) TRECOT TECHNICAL REPORT 63-52 NOVEMBER 1963, 101 PP, AD 429 114

* ABSTRACT *

AN INVESTIGATION OF THE INFLUENCE OF LOW-ALTITUDE HIGH-SPEED FLIGHT CONDITIONS ON INFLIGHT OPERATOR PERFORMANCE OF SURVEILLANCE-CENTERED TASKS IS REPORTED. SIX ARMY PILOTS AND FOUR ARMY OBSERVERS FLEW APPROXIMATELY 278 HOURS ON SIMULATED THREE-HOUR MISSIONS INVOLVING FIVE RMS GUST INTENSITY LEVELS AND TWO AIRSPEEDS. THE FLIGHTS WERE MADE IN A MOVING BASE SIMULATOR THAT HAD A TOTAL TRAVEL OF APPROXIMATELY 12 FEET, AND ACCELERATION CAPABILITY OF $+ 8R - 6 G$, A FUNCTIONAL CONTROL SYSTEM, AND AN ASSOCIATED ANALOG COMPUTER FOR OBTAINING SOLUTIONS TO EQUATIONS OF MOTION OF A MECHANIZED AIRCRAFT. DATA WERE ANALYZED IN TERMS OF HUMAN PERFORMANCE ASPECTS OF THE MISSIONS.

PRILLE, R.V. AND MORAN, W.A. DYNAMIC FLYING QUALITIES CRITERIA EVALUATION. REPORT AFFDL-TR-74-142, AIR FORCE FLIGHT DYNAMICS LABORATORY, AIR FORCE SYSTEMS COMMAND, WRIGHT-PATTERSON AFB, OHIO, JAN. 1975.

* ABSTRACT *

AN EVALUATION OF MIL-F-8785B (ASG) LONGITUDINAL AND LATERAL-DIRECTIONAL DYNAMIC FLYING QUALITIES REQUIREMENTS AND OTHER CRITERIA WAS CONDUCTED USING SIMULATOR DATA COLLECTED DURING THE DEVELOPMENT OF THE F-15 FLIGHT CONTROL SYSTEM. BOTH OPEN AND CLOSED (PILOT FUNCTION INCLUDED) LOOP METHODS WERE EVALUATED. THE APPLICABILITY TO HIGHLY CONTROL-AUGMENTED AIRCRAFT WAS DETERMINED. THE DATA BASE CONSISTED OF THE SIMULATOR RUN SCHEDULE, PILOT RATINGS AND PILOT COMMENTS, AERODYNAMICS, CONTROL SYSTEM

DESCRIPTION AND OTHER MATERIAL. A LITERATURE SURVEY OF FLYING QUALITIES CRITERIA IS PRESENTED.

BUCKOLT, R. "A WORKING BIBLIOGRAPHY ON THE EFFECTS OF MOTION ON HUMAN PERFORMANCE". BEHAVIORAL SCIENCES LABORATORY, 657TH AEROSPACE MEDICAL RESEARCH LABORATORIES, AEROSPACE MEDICAL DIVISION, AIR FORCE SYSTEMS COMMAND, WRIGHT-PATTERSON AIR FORCE BASE, OHIO, TECHNICAL DOCUMENTARY REPORT NO. MRL-TDR-62-77, JULY 1962.

* ABSTRACT *

IN THIS BIBLIOGRAPHY A LIST OF REPORTS IS COMPILED FROM A NUMBER OF DISCIPLINES WHICH BEAR ON THE PROBLEM OF MOTION AND ITS EFFECTS ON HUMAN PERFORMANCE. PSYCHOPHYSIOLOGICAL REPORTS IN THE AREA OF SPATIAL ORIENTATION, PERCEPTION AND RECEPTOR MECHANISMS PROVIDE BACKGROUND ON THE HUMAN ORGANISM IN RELATION TO MOTION STIMULI. THE EFFECTS OF AEROSPACE VEHICLE MOTION ARE REPRESENTED BY A COMPILATION OF STUDIES OF PERFORMANCE UNDER ACCELERATION, VIBRATION, AND BUFFETING, TUMBLING AND WEIGHTLESSNESS. FINALLY REPORTS ON TRAINING AND MOTION SIMULATION, EQUIPMENT AND METHODOLOGY AND GENERAL ANALYSES OF THE WHOLE PROBLEM AREA ARE PRESENTED.

BUCKOLT, R., SHERMAN, F., GOLDSMITH, T.C., AND VITALE, F.A. "THE EFFECT OF VARIATIONS IN MOTION FIDELITY DURING TRAINING ON SIMULATED LOW-ALTITUDE FLIGHT", AMRL-TDR-63-108, WRIGHT-PATTERSON AFB, DAYTON, OHIO, DECEMBER 1963.

* ABSTRACT *

INVESTIGATION OF TERRAIN CLEARANCE TASK USED GROUPS OF 8 SUBJECTS IN EITHER STATIC COCKPIT, OR QUASI-DYNAMIC COCKPIT (1 C/S SINUSOIDAL SIGNAL TO GIVE IMPRESSION OF BUFFET) OR DYNAMIC COCKPIT (PITCH AND HEAVE ACCELERATIONS, BASED ON VARIOUS SEVERITIES OF TURBULENCE LIKELY TO BE ENCOUNTERED AT 250 FEET ABOVE TERRAIN). PERFORMANCE WORST IN STATIC COCKPIT, BEST IN REALISTIC DYNAMIC.

INVESTIGATION COMPARED PERFORMANCE OF GROUPS OF 12 SUBJECTS IN A REPRESENTATIVE SIMULATION (PITCH, ROLL, AND HEAVE ACCELERATIONS) AFTER THEY HAD LEARNED THE TASK IN EITHER THE STATIC COCKPIT, OR THE FULLY DYNAMIC COCKPIT, OR THE COCKPIT DRIVEN BY 33% OF THE FULLY DYNAMIC MOTIONS. BOTH GROUPS, TRAINED WITH MOTION CUES PERFORMED BETTER THAN THE ONE TRAINED WITHOUT BUT COULD NOT BE DIFFERENTIATED ON ANY OF 4 PERFORMANCE MEASURES.

BUCKLEY, J.P. - AERONAUTICAL INSTRUCTING DEVICE
 PATENT NO. 1,865,828
 FILED JULY 3, 1929 GRANTED JULY 5, 1932

ABSTRACT

 BURKE, J., DUNN, R.S., CLUSTERBERRY, J.C., KEY, D.L., SINACORE, J.P., AND XENAKIS, G. A TECHNICAL ASSESSMENT OF U.S. ARMY FLIGHT SIMULATION CAPABILITY AND REQUIREMENTS FOR AVIATION RESEARCH AND DEVELOPMENT. ASRD REPORT 75-1, ADVANCED SYSTEMS RESEARCH OFFICE, U.S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY, AMES RESEARCH CENTER, MOFFETT FIELD, CA, APRIL 1975.

* ABSTRACT *

THIS REPORT PRESENTS A REVIEW OF THE FUNCTIONS, STATUS AND FUTURE NEEDS FOR GROUND-BASED FLIGHT SIMULATION WITHIN THE ARMY MATERIAL COMMAND (AMC). IT IS RESTRICTED TO THE CONSIDERATION OF SIMULATORS FOR AIRCRAFT SYSTEMS RESEARCH AND DEVELOPMENT AND COMPLEMENTS A SIMILAR STUDY BY THE U.S. ARMY TRAINING DEVICE AGENCY (USATA) ADDRESSING SIMULATION FOR FLIGHT TRAINING. THE REPORT WAS PREPARED AT THE REQUEST OF AMC, BY THE U.S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY (AMRDL) WITH ASSISTANCE FROM THE NATIONAL AERONAUTICS AND SPACE AGENCY (NASA) AMES RESEARCH CENTER. DATA FOR THE INVESTIGATION WAS OBTAINED FROM QUESTIONNAIRES, ON-SITE VISITS, AND INTERVIEWS WITH KEY PERSONNEL.

THE GENERAL CONCLUSIONS ARE THAT SEVERAL ORGANIZATIONS WITHIN AMC HAVE LEGITIMATE NEEDS FOR FLIGHT SIMULATION IN THEIR AIRCRAFT SYSTEMS RESEARCH AND DEVELOPMENT EFFORTS. GENERALLY THESE NEEDS CAN BE SATISFIED BY LIMITED CAPABILITY, SPECIAL PURPOSE SIMULATORS. THERE IS ALSO A NEED FOR AN ADVANCED CAPABILITY, MULTIPURPOSE, HIGH CONFIDENCE SIMULATION THAT CAN BE USED TO STUDY THE COMPLETE RANGE OF PROBLEMS IN PILOT-AIRCRAFT SYSTEM INTEGRATION.

SUCH FACILITIES ARE EXPENSIVE TO DEVELOP AND OPERATE, SO DUPLICATION MUST BE AVOIDED THROUGH A WELL MANAGED PROGRAM COORDINATED THROUGHOUT AMC. SINCE THE AVIATION SYSTEMS COMMAND (AVSCOM) HAS THE MISSION OF TOTAL AIRCRAFT SYSTEM INTEGRATION, IT IS PROPOSED THAT THIS COMMAND BE ASSIGNED THE MISSION OF DEVELOPING A HIGH CONFIDENCE SIMULATION CAPABILITY, AND COORDINATING ITS DEVELOPMENT AND USE WITH THE DEVELOPMENT AND USE OF OTHER FLIGHT SIMULATOR FACILITIES THROUGHOUT AMC. PLANS ARE PRESENTED FOR DEVELOPMENT OF SUCH A CAPABILITY AND FORMULATION OF ITS OVERALL MANAGEMENT.

NAVTRAEQUIPCEN IH-298

G. BURNY - COCKPIT ASSEMBLY FOR FLIGHT SIMULATOR
PATENT NO. 3,229,988
FILED MAY 25, 1972 GRANTED AUG. 20, 1974

NO ABSTRACT

BURROWS, A.A. CONTROL FEEL AND THE DEPENDENT VARIABLE. 'HUMAN FACTORS', VOL. 7, 5, OCT 1965, 413-421.

* ABSTRACT *

THE DEFINITION AND EFFECTS OF FEEL AT THE CONTROL-LIMB INTERFACE ARE DISCUSSED TOGETHER WITH SOME CURRENT PROBLEMS AND EXPERIMENTS. THE RELATIONSHIP WITH FEEL BEARS TO THE ERROR TERM USED IN DESCRIBED COMPLEX TRACKING BEHAVIOR, IS DESCRIBED AND RECOMMENDATIONS MADE FOR FURTHER RESEARCH.

BURROWS, A.A. AND WHITE, R.T. HUMAN FACTORS IN FLIGHT TRAINING: SIMULATION ENTERS A NEW ERA DOUGLAS AIRCRAFT COMPANY PAPER NO. 5279. PRESENTED TO THE INTERNATIONAL FLIGHT SAFETY SYMPOSIUM, DISNEYLAND HOTEL, ANAHEIM, CALIFORNIA OCTOBER 9, 1968

* ABSTRACT *

THE CURRENT INTEREST IN NON-MILITARY SIMULATION IN TRAINING IS PROMISINGLY EMERGENT BUT LARGELY FISCAL. CAN COSTLY TRAINING TIME BE REDUCED OR FLIGHT TIME REPLACED, THUS ALSO REMOVING ACCIDENT HAZARD. HOWEVER, THE INEVITABLE TREND TOWARD MEASUREMENT MAY WELL CAUSE PROFICIENCY TO BECOME A CONCRETE SET OF DATA. THIS WILL NOT BE EFFECTIVE, THOUGH IF THE TRAINING INTERESTS DO NOT EMPLOY PROFESSIONAL SCIENTISTS, NOTABLY HUMAN FACTORS PERSONNEL, WHO ARE COMPETENT IN THE DEFINITION, MEASUREMENT AND EVALUATION OF SKILLS TO BE TRAINED IN SIMULATIVE DEVICES IN PARTICULAR AND TRAINING SYSTEMS IN GENERAL. IT IS IN THE INTERESTS OF BOTH THE FLYERS AND THEIR ORGANIZATIONS TO ENSURE THAT TRAINING TOOLS EMERGE HEALTHILY AS MEANS OF MEASUREMENT AS WELL AS OF TEACHING AND THAT THE DATA IS HANDLED WELL TO DERIVE FACTS OF VALUE.

CALLANEN, S.E. - MOTION SYSTEM FOR FLIGHT SIMULATION.
PATENT NO. 3,352,029
FILED MAY 11, 1966 GRANTED NOV. 14, 1967

NO ABSTRACT

CALLANEN, B.E.

MELPAR, INC. FALLS CHURCH VIRGINIA

MOTION SYSTEM WITH THREE RECIPROCATING ACTUATORS FOR FLIGHT
SIMULATION. PATENT NO. 3645011, FEBRUARY 29, 1972

* ABSTRACT *

A MOTION SYSTEM FOR GENERAL PURPOSE FLIGHT SIMULATION INCLUDES THREE SPACED-APART HYDRAULIC ACTUATORS FOR IMPARTING TRANSLATION TO RESPECTIVELY ASSOCIATED RECIPROCATABLE PISTONS OR RAMS. ONE OF THE ACTUATORS IS POSITIONED VERTICALLY IN A PLANE CONTAINING THE LONGITUDINAL OR ROLL AXIS OF A GROUNDED FLIGHT TRAINER AND THE OTHER TWO ACTUATORS ARE EQUALLY SPACED FROM THE ROLL AXIS AT VERTICAL POSITIONS ON EITHER SIDE OF THE TRAINER IN A PLANE CONTAINING ITS TRANSVERSE AXIS. THE RECIPROCAL SUPPORT RAMS ARE SO PIVOTALLY CONNECTED TO AND SUPPORT THE TRAINER AT THE FORWARD END AND RESPECTIVE SIDES SO TO ENABLE THE TRAINER TO UNDERGO INDEPENDENT ROTATION ABOUT ITS PITCH AND ROLL AXIS, SUCH THAT VERTICAL TRANSLATION OF THE FORWARD RAM PRODUCES ROTATION OF THE TRAINER ABOUT ITS PITCH AXIS AND THAT UNEQUAL VERTICAL TRANSLATIONS OF BOTH OF THE OTHER RAMS PRODUCES ROTATION OF THE TRAINER ABOUT ITS ROLL AXIS.

CALVERT, E.S. THE THEORY OF VISUAL JUDGMENTS IN MOTION AND ITS APPLICATION TO THE DESIGN OF LANDING AIDS FOR AIRCRAFT. TRANS. ILLUM. ENG. SOC., VOL 22, NO 10, 1957, PP271-297

* ABSTRACT *

THIS PAPER IS INTENDED TO BRING THE THEORY OF THE VISUAL AIDS UP TO DATE, AND TO DISCUSS VARIOUS PRACTICAL METHODS OF INCREASING THE SAFETY OF THE APPROACH AND LANDING OPERATION.

ARGUMENTS ARE PUT FORWARD TO SHOW THAT THE GUIDANCE IN THE VERTICAL PLANE NEEDS TO BE IMPROVED, PARTICULARLY IN VISIBILITY SOMEWHAT ABOVE THE LIMITING VISIBILITY, AND A NEW FORM OF ANGLE OF APPROACH INDICATOR IS DESCRIBED, WHICH PROMISES TO ACHIEVE THIS RESULT. THE BEAM SPREADS OF THE APPROACH LIGHTS SHOULD BE INCREASED AND FITTINGS FOR PROVIDING GUIDANCE FOR CIRCLING APPROACHES SHOULD BE DEVELOPED. THE BRITISH DESIGN OF FLASH-TYPE RUNWAY LIGHT HAS PROVED SATISFACTORY IN ACTUAL OPERATIONS, AND AS A RESULT, LANDING MATS HAVE NOW BECOME PRACTICABLE, EVEN ON EXISTING RUNWAYS.

CANFIELD, A.A., COMREY, A.L., AND WILSON, R.C. STUDY OF REACTION TIME TO LIGHT AND SOUNDS AS RELATED TO INCREASED POSITIVE RADIAL ACCELERATION. JOURNAL OF AVIATION MEDICINE, 20, 1949.

* ABSTRACT *

THE REACTION TIME TO BOTH LIGHT AND SOUND STIMULI BECOMES SIGNIFICANTLY LONGER UNDER CONDITIONS OF INCREASED RADIAL ACCELERATIONS. THE SUPERIORITY OF REACTION TO SOUND, IN ADDITION TO THE KNOWN FAILURE OF SIGHT AT CRUCIAL G-LEVELS, SUGGESTS THE ADVISABILITY OF PRESENTING IMPORTANT SIGNALS TO THE PILOT IN THE AUDITORY SENSE MODALITY RATHER THAN THE VISUAL. THIS IS ESPECIALLY VITAL IN THOSE CASES WHERE SUCH SIGNALS DEMAND EMERGENCY ACTION. THE TREMENDOUS SPEED OF THE AIRCRAFT OF TODAY AND TOMORROW WILL NECESSITATE ACTION TO CONSERVE EVERY SPLIT SECOND. TAKING STEPS SUCH AS THOSE SUGGESTED HERE SHOULD HELP TO TAKE SOME OF THE BURDEN FROM THE LIMITING FACTOR IN AIRCRAFT DESIGN - THE PILOT.

CANFIELD, A.A., COMREY, R.L. AND WILSON, R.C. 'INFLUENCE OF INCREASED POSITIVE G ON REACHING MOVEMENTS.' 'J. OF APPLIED PSYCHOLOGY', VOLUME 37, NO. 3, 1953.

* ABSTRACT *

FROM THE RESULTS OF THIS RESEARCH, CERTAIN CONCLUSIONS ABOUT THE EFFECT OF INCREASED POSITIVE RADIAL ACCELERATION ON REACHING MOVEMENTS MAY BE ADVANCED.

1. BOTH THE SPEED AND ACCURACY OF REACHING MOVEMENTS AT INCREASED G LEVELS ARE SERIOUSLY IMPAIRED, THE DEGREE OF IMPAIRMENT BEING ROUGHLY EQUIVALENT TO THE AMOUNT OF FORCE IMPOSED.
2. THE KINESTHETIC CUES GOVERNING THE THRUST OF THE ARM UNDER NORMAL CIRCUMSTANCES ARE INADEQUATE TO MAINTAIN SIMILAR ACCURACY OR SPEED UNDER RADIAL ACCELERATIVE CONDITIONS.
3. DUE TO THE INCREASED WEIGHT OF THE ARM AND THE INADEQUACY OF THE NORMAL KINESTHETIC CUES, TWO TYPES OF ERRORS ARE FOUND, ONE BEING THE NEGATIVE INERTIA ERROR AND THE OTHER THE ERROR OF DOWNWARD TENDENCY.
4. THE MOST FAVORABLE LOCATION OF CONTROLS FOR THE PILOT OF HIGH-SPEED AIRCRAFT, BOTH FROM THE STANDPOINT OF SPEED AND ACCURACY, IS TO THE SIDE OF THE PILOT'S PREFERRED HAND AND BELOW ITS NORMAL RESTING POINT.
5. EMERGENCY CONTROLS THAT MIGHT HAVE TO BE MANIPULATED UNDER CONDITIONS OF INCREASED POSITIVE RADIAL ACCELERATION SHOULD BE NO SMALLER THAN TWO INCHES IN DIAMETER IF A PUSHING MOTION IS REQUIRED.

K.L. CARREL - MOTION SIMULATOR
 PATENT NO. 3,295,224
 FILED DEC. 7, 1964 GRANTED JAN. 3, 1967

* ABSTRACT *

A MOTION SIMULATOR CAPABLE OF MOTION IN ALL SIX DEGREES OF FREEDOM IS PROVIDED HAVING A PLATFORM PROVIDING THREE POINTS IN A PLANE AND A SUPPORT BASE PROVIDING THREE POINTS IN ANOTHER PLANE. SIX EXTENSIBLE MEMBERS ARE EMPLOYED EACH CONNECTED AT ONE END TO THE SUPPORT BASE AND AT THE OTHER END TO THE PLATFORM AND CONNECTING ADJACENT POINTS OF THE SUPPORT BASE AND PLATFORM, THE EXTENSIBLE MEMBERS BEING POWERED AND CONTROLLED FOR PROVIDING ANY OF THE MOTIONS OF THE PLATFORM BY SELECTIVE CHANGES IN LENGTH OF THE EXTENSIBLE MEMBERS. MEANS ON THE PLATFORM IS PROVIDED FOR EXPERIENCING MOTION PRODUCED BY MOVEMENT OF THE PLATFORM.

F.M. CARDULLO, ET AL - ADVANCED G SEAT FOR AIRCRAFT SIMULATION
PATENT NO. 3,983,640
FILED NOV. 6, 1974 GRANTED OCT. 5, 1976

NO ABSTRACT

CARD, P.W.
SOME FACTORS INFLUENCING TRANSFER OF SIMULATOR TRAINING, HUMRRB
PROFESSIONAL PAPER 1-76, PRESENTED AT THE THIRD FLIGHT SIMULA-
TION SYMPOSIUM OF THE ROYAL AERONAUTICAL SOCIETY, LONDON,
ENGLAND, APRIL 1976

* ABSTRACT *

MOTION FIDELITY

NOT MUCH MORE IS KNOWN ABOUT THE INFLUENCE OF MOTION UPON
SIMULATOR TRAINING EFFECTIVENESS THAN ABOUT VISUAL DISPLAY.
ALTHOUGH MOTION SIMULATION HAS REPRESENTED A SIGNIFICANT
PORTION OF THE COST OF SIMULATOR PROCUREMENT AND OPERATION FOR
A NUMBER OF YEARS, THE INVESTIGATION OF THE INFLUENCE OF
MOTION UPON SIMULATOR TRAINING EFFECTIVENESS HAS BEEN LARGELY
IGNORED. THE FIRST SIGNIFICANT STUDY INVOLVING SIMULATOR
MOTION IN THE TRANSFER OF PILOT TRAINING WAS REPORTED IN 1975
BY JACOBS AND RUSCOE.

THE RESULTS OF THE JACOBS AND RUSCOE STUDY PROVIDE EVIDENCE
THAT TRANSFER MAY NOT BENEFIT FROM THE PRESENCE OF NORMAL
WASHOUT COCKPIT MOTION. IN THAT STUDY, TRAINING RECEIVED IN A
TWO-AXIS NORMAL WASHOUT MOTION CONDITION, COMPARED WITH
TRAINING IN THE SAME DEVICE WITHOUT MOTION, RESULTED IN NON-
SIGNIFICANT DIFFERENCES IN AMOUNT OF TRANSFER TO THE AIRCRAFT
FOR THESE TWO CONDITIONS. THERE WAS HOWEVER, SIGNIFICANT
POSITIVE TRANSFER FOR BOTH MOTION AND NO-MOTION CONDITIONS.
SIMILAR RESULTS HAVE BEEN OBTAINED IN AN UNPUBLISHED U. S.
AIR FORCE UNDERGRADUATE PILOT TRAINING STUDY INVOLVING A

MORE SOPHISTICATED SIX-AXIS MOTION SYSTEM.

THE JACOBS AND RUSCOE FINDING THAT, AT LEAST WITH BEGINNING TRAINEES, THE PRESENCE OF MOTION MAY NOT INCREASE SIMULATOR TRAINING EFFECTIVENESS MUST BE TREATED WITH CAUTION UNTIL INVESTIGATED FURTHER, SINCE THERE ARE OTHER STUDIES SUGGESTING THAT, AT LEAST UNDER SOME CIRCUMSTANCES, MOTION MAY BE DESIRABLE EVEN IF NOT ESSENTIAL. FOR EXAMPLE, FEDDERSON (1962) REPORTED A SLIGHT ADVANTAGE IN FAVOR OF A MOTION-SIMULATOR TRAINED GROUP OVER A NO-MOTION GROUP DURING BRIEF TRANSFER TRIALS HOVERING A HELICOPTER. MORE IMPORTANTLY, PERHAPS, THE MOTION GROUP IN HIS STUDY REACHED ASYMPTOTIC PERFORMANCE IN THE SIMULATOR MORE RAPIDLY, SUGGESTING THAT SIMULATORS WITH MOTION MAY PROVIDE MORE EFFICIENT TRAINING, EVEN IF NOT MORE EFFECTIVE TRAINING. NASA RESEARCHERS HAVE FOUND THAT THE CORRELATION BETWEEN PILOT PERFORMANCE IN AN AIRCRAFT AND IN A SIMULATOR INCREASES WITH THE ADDITION OF SIMULATOR MOTION CUES WHERE SUCH CUES HELP THE PILOT IN COPING WITH A HIGHLY DAMPED OR UNSTABLE VEHICLE OR A SLOUGGISH CONTROL SYSTEM OR UNDER SOME CIRCUMSTANCES, WHERE THE CONTROL SYSTEM IS TOO SENSITIVE. WHERE THE AIRCRAFT IS EASY TO FLY, HOWEVER, AS IS THE CASE WITH THE AIRCRAFT USED IN THE JACOBS AND RUSCOE STUDY (PIPER CHEROKEE) AND IN THE AIR FORCE STUDY (T-37), MOTION HAS NO EFFECT. IN ANOTHER NASA STUDY (DOUVILLIER ET AL. 1960) OF THE EFFECTS OF SIMULATOR MOTION ON PILOTS PERFORMANCE OF A TRACKING TASK, THE RESULTS FROM A MOVING FLIGHT SIMULATOR RESEMBLED THE PILOTS PERFORMANCE OF A TRACKING TASK, THE RESULTS FROM A MOVING FLIGHT SIMULATOR RESEMBLED THE RESULTS FROM FLIGHT MUCH MORE THAN DID THOSE FROM A MOTIONLESS SIMULATOR. HUCKLESTON AND FOLFE (1971) REPORTED THAT, USING SIMULATORS WITHOUT MOTION, EXPERIENCED PILOTS ARE OFTEN ABLE TO ACHIEVE ACCEPTABLE LEVELS OF PERFORMANCE, BUT THEIR PATTERNS OF CONTROL RESPONSE SHOW THAT THEIR PERFORMANCE IS ACHIEVED USING A STRATEGY DIFFERENT FROM THAT USED IN A DYNAMIC TRAINING ENVIRONMENT. SINCE CONTROL STRATEGIES MAY BE IMPORTANT DURING IN-FLIGHT EMERGENCY MANEUVERS WHERE TRANSFER OF TRAINING RESEARCH IS NOT FEASIBLE, IT WOULD APPEAR INADVISABLE TO ELIMINATE MOTION FROM ALL SIMULATORS UNTIL FURTHER INVESTIGATION SHOWS THE GENERALITY OF THE JACOBS AND RUSCOE FINDINGS. AT THE PRESENT TIME, WE CANNOT BE CERTAIN OF THE ROLE OF MOTION IN SIMULATOR TRAINING EFFECTIVENESS AND EFFICIENCY.

 CASE, P.W. PLATFORM MOTION AND SIMULATOR TRAINING EFFECTIVENESS.
 SEVILLE RESEARCH CORPORATION. PAPER SUBMITTED FOR 1977 NTEC/
 INDUSTRY CONFERENCE.

* ABSTRACT *

SEVERAL RECENT STUDIES REPORTED THAT SIMULATOR MOTION DID NOT BENEFIT SUBSEQUENT FLIGHT PERFORMANCE. OTHER STUDIES HAVE REPORTED VARIOUS EFFECTS OF MOTION UPON PILOT PERFORMANCE IN

SIMULATORS. THESE POSSIBLY CONTRADICTORY FINDINGS ARE EXAMINED IN THE LIGHT OF RECENT DISTINCTIONS MADE BETWEEN MANEUVER AND DISTURBANCE MOTION. THE STUDIES IN WHICH SIMULATOR MOTION DID NOT BENEFIT TRANSFER PREDOMINANTLY EMPLOYED MANEUVER MOTION CUES, WHEREAS THE OTHER GROUP OF STUDIES INCORPORATED MORE DISTURBANCE MOTION CUES. PILOT REACTIONS TO SIMULATOR MOTION ALSO WERE EXAMINED IN TERMS OF MANEUVER VS. DISTURBANCE MOTION, AND IT WAS NOTED THAT JUDGMENTS OF THE TRAINING VALUE OF SIMULATOR MOTION WERE RELATED TO THE MANEUVER-DISTURBANCE DISTINCTION. IT IS CONCLUDED THAT MANEUVER MOTION MAY BE OF LITTLE POTENTIAL TRAINING VALUE, UNDER MANY CIRCUMSTANCES, AND DATA NECESSARY TO AN ADEQUATE SIMULATION OF DISTURBANCE MOTION MAY NOT BE AVAILABLE. AN ANALYSIS OF THE TRAINING REQUIREMENTS ASSOCIATED WITH DISTURBANCE MOTION IS NEEDED.

CARE, P.W., JR. AND ISLEY, R.N. HELICOPTER TRAINEE PERFORMANCE FOLLOWING SYNTHETIC FLIGHT TRAINING, THE DEPARTMENT OF THE ARMY (THE GEORGE WASHINGTON UNIVERSITY, HUMAN RESOURCES OFFICE, HUMRRB DIVISION NO. 6, ALEXANDRIA, VIRGINIA), PROFESSIONAL PAPER 7-66, NOVEMBER 1966, 15 PP. AD 646 157.

* ABSTRACT *

IN A STUDY TO DETERMINE WHETHER THE USE OF A SYNTHETIC HELICOPTER FLIGHT TRAINING DEVICE WOULD IMPROVE THE SUBSEQUENT PRIMARY FLIGHT PERFORMANCE OF TRAINEES AT THE U. S. ARMY PRIMARY HELICOPTER SCHOOL, TWO GROUPS WERE TRAINED TO FLY A CAPTIVE HELICOPTER MOUNTED ON A GROUND EFFECTS MACHINE. THE DEVICE HAD THE APPROXIMATE HANDLING CHARACTERISTICS OF A FREE-FLYING VEHICLE, YET IT ALLOWED THE TRAINEES TO OBTAIN AERONAUTICAL EXPERIENCE NOT OTHERWISE POSSIBLE AT THEIR LEVEL OF TRAINING. IT WAS FOUND THAT THE DEVICE-TRAINED CONTROLS WERE SIGNIFICANTLY LESS LIKELY TO BE ELIMINATED FROM SUBSEQUENT PRIMARY HELICOPTER TRAINING FOR REASONS OF FLIGHT AND SKILLS DEFICIENCY. FURTHER, MEASURES OF RELATIVE PERFORMANCE DURING PRIMARY FLIGHT TRAINING INDICATED THE DEVICE-TRAINED GROUP SOLD THE HELICOPTER EARLIER AND MADE BETTER FLIGHT GRADES DURING THE PRE-SALE PHASE OF TRAINING THAN DID THE CONTROLS. IMPLICATIONS OF THE DEVICE CONCEPTS INVESTIGATED IN THIS STUDY ARE ILLUSTRATED.

CARE, P.W., JR., ISLEY, R.N. AND JOLLEY, B.B. THE CAPTIVE HELICOPTER AS A TRAINING DEVICE: EXPERIMENTAL EVALUATION OF A CONCEPT. HUMRRB TECHNICAL REPORT 68-9, JUNE 1968.

* ABSTRACT *

THE RESEARCH OBJECTIVE WAS TO DETERMINE THE EFFECTIVENESS OF A DEVICE CONCEPT FOR HELICOPTER CONTACT FLIGHT TRAINING AND THE USEFULNESS OF SUCH A DEVICE FOR PREDICTING PERFORMANCE DURING

SUBSEQUENT FLIGHT TRAINING. THE DEVICE WAS A COMMERCIALY AVAILABLE CAPTIVE HELICOPTER ATTACHED TO A GROUND EFFECTS MACHINE. TWO EXPERIMENTAL GROUPS OF TRAINEES RECEIVED 3 1/4 OR 7 1/4 HOURS OF DEVICE TRAINING PRIOR TO PRIMARY HELICOPTER TRAINING. IN COMPARISON WITH CONTROL GROUPS, BOTH DEVICE TRAINED GROUPS (A) WERE SIGNIFICANTLY LESS LIKELY TO BE ELIMINATED FROM SUBSEQUENT FLIGHT TRAINING FOR REASONS OF FLYING DEFICIENCY; (B) REQUIRED LESS FLIGHT TRAINING TO ATTAIN THE PROFICIENCY REQUIRED TO SOLO THE HELICOPTER; AND (C) RECEIVED HIGHER GRADES DURING EARLY TRAINING. TRAINEES WHO PERFORMED WELL ON THE TRAINING DEVICE TENDED TO PERFORM WELL DURING SUBSEQUENT FLIGHT TRAINING. INSTRUCTORS USING DEVICES SUCH AS THIS ONE NEED NOT BE PROFICIENT IN THE HELICOPTER USED FOR SUBSEQUENT FLIGHT TRAINING. (AUTHOR)

CARR, P.W., JOLLEY, O.B., ISLEY, R.N. AND WRIGHT, R.H.
DETERMINING TRAINING DEVICE REQUIREMENTS IN FIXED WING AVIATOR
TRAINING. HLMRRB TECHNICAL REPORT 72-11, APRIL 1972.

* ABSTRACT *

A SYSTEMATIC STUDY OF ALL FIXED WING PILOT TRAINING PROGRAMS AT THE U. S. ARMY AVIATION SCHOOL WAS CONDUCTED IN FY 1968. THE OBJECTIVE WAS TO DETERMINE WHETHER TRAINING MIGHT BE MADE MORE EFFECTIVE THROUGH GREATER USE OF SYNTHETIC FLIGHT TRAINING EQUIPMENT AND, IF SO, TO SPECIFY THE MAIN CHARACTERISTICS OF APPROPRIATE EQUIPMENT. SECONDARY OBJECTIVES WERE TO ASSIST IN DEVELOPING LOW COST DEVICES FOR ONE COURSE AND TO DETERMINE THE FEASIBLE COST-EFFECTIVENESS OF A COMMERCIALY AVAILABLE DEVICE IN ANOTHER. A METHOD WAS DEVELOPED WHICH IDENTIFIED SPECIFIC AND DIFFERENTIAL NEEDS FOR SYNTHETIC EQUIPMENT IN EACH COURSE AND DETERMINED SUITABILITY OF EXISTING EQUIPMENT TO MEET THOSE NEEDS. A GENERALIZABLE, SYSTEMATIC METHOD FOR DETERMINING REQUIREMENTS FOR SYNTHETIC TRAINING EQUIPMENT IN EXISTING TRAINING PROGRAMS RESULTED.

THREE MOTION RELEVANT PARAGRAPHS

1. THE PRIMARY PURPOSE OF A SIMPLE, SYMBOLIC VISUAL DISPLAY, AS DESCRIBED, IS TO PROVIDE THE TRAINEE WITH ATTITUDE CONTROL CLUES IN RELATION TO AN EXTERNAL REFERENCE-THE RELATIVE ANGLES BETWEEN THE VERTICAL, HORIZONTAL, AND LATERAL AXES OF THE TRAINER AND THE HORIZON. IN ORDER TO VARY THESE ANGLES, MOTION MUST BE REPRESENTED EITHER IN THE VISUAL DISPLAY OR IN THE COCKPIT. SIMULATION ENGINEERING PERSONNEL INDICATE THAT MOTION OF THE COCKPIT GENERALLY IS FEASIBLE. FROM THE TRAINING STAND-POINT, COCKPIT MOTION HAS OTHER ADVANTAGES AS WELL. FOR EXAMPLE, IT MAKES THE TRAINING TASK APPEAR MORE 'REALISTIC' TO THE TRAINEE AND THUS ENHANCES HIS MOTIVATION TO USE THE DEVICE. COCKPIT MOTION PREFERABLE IN THE PITCH, ROLL AND YAW DIMENSIONS IS CONSIDERED TO BE AN ESSENTIAL CHARACTERISTIC FOR A PRIMARY

CONTACT FLIGHT TRAINING DEVICE.

2. MANY OF THE CUES ASSOCIATED WITH OPERATION OF A HIGH-PERFORMANCE AIRCRAFT ARE PROPRIOCEPTIVE IN NATURE, THAT IS, THEY ARE ASSOCIATED WITH CHANGES IN BODY POSITION AND ORIENTATION. THE RELATIVELY SUBTLE CUES ASSOCIATED WITH ACCELERATION, DECELERATION, AND TILT - THE CUES THAT ALERT HIGHLY PROFICIENT PILOTS TO OUT-OF-TOLERANCE CONDITIONS BEFORE THEY ARE DETECTED FROM INSTRUMENT INDICATIONS - ARE IN THIS CATEGORY, AND THEIR SIMULATION REQUIRES THE PHYSICAL DISPLACEMENT OF THE BODY. SUCH IS A PRIMARY FUNCTION OF THE MORE SOPHISTICATED MULTI-AXIS FLIGHT SIMULATOR MOTION PLATFORMS. THE CUES THESE PLATFORMS PROVIDE ENABLE PILOTS TO DETECT CHANGES IN AIRCRAFT ATTITUDE AND SPEED MORE RAPIDLY THAN MIGHT OTHERWISE BE POSSIBLE. MOTION IS PARTICULARLY USEFUL TO EXPERIENCE PILOTS WHO HAVE LEARNED TO ATTEND TO THE MOTION CUES ASSOCIATED WITH THE ONSET OF SYSTEMS MALFUNCTIONS. CONSEQUENTLY, MOTION MUST BE MORE FAITHFULLY REPRODUCED FOR THEM IN A TRAINING DEVICE THAN FOR INEXPERIENCED PILOTS SUCH AS O/WBFWAC TRAINEES. BECAUSE OF SPACE LIMITATIONS, HOWEVER, ONLY QUALITATIVE SIMULATION OF MOTION CAN BE OBTAINED IN SUCH PLATFORMS. A SIMULATOR FOR THE MOHAWK SHOULD INCORPORATE A MOTION PLATFORM THAT PROVIDES APPROPRIATE PSYCHOLOGICAL CUES ASSOCIATED WITH VIBRATION AND WITH THE DISPLACEMENTS OF THE AIRCRAFT ALONG THE ROLL, PITCH, AND YAW AXES AT A MINIMUM, AND POSSIBLY ALONG THE VERTICAL AXIS AS WELL. IT SHOULD BE NOTED THAT FLIGHT SIMULATORS UNDER DEVELOPMENT FOR THE BOEING 747 AND THE SST WILL HAVE FORE-AFT AND LATERAL TRANSLATION MOTION IN ADDITION TO THESE.

3. THE ADDITION OF MOTION TO SYNTHETIC INSTRUMENT FLIGHT TRAINERS APPEARS TO HAVE A MINOR BUT USEFUL EFFECT UPON THE DEVELOPMENT OF SKILLS IN CONTROL OF THE AIRCRAFT ON INSTRUMENTS AND MOTION PROBABLY IS QUITE USEFUL FOR THE RECOGNITION OF UNUSUAL FLIGHT CONDITIONS AND MALFUNCTIONS SUCH AS LOSS OF AN ENGINE. ADDING MOTION TO SUCH TRAINERS FOR BEGINNING INSTRUMENT TRAINEES MIGHT BE DIFFICULT TO JUSTIFY FOR THE SOLE PURPOSE OF TRAINING IN AIRCRAFT CONTROL. HOWEVER, IN VIEW OF THE VALUE MOTION MAY PROVIDE FOR RECOGNIZING THE ONSET OF UNUSUAL CONDITIONS AND MALFUNCTIONS PLUS THE GREATER TRAINEE ACCEPTANCE OF DEVICES INCORPORATING MOTION, THE COST OF A SIMPLE MOTION PLATFORM PROBABLY IS JUSTIFIED. A DEVICE THAT PROVIDES QUALITATIVE SIMULATION OF THREE-AXIS MOTION (PITCH, ROLL, AND YAW) PROBABLY WOULD BE ADEQUATE FOR THE TRAINING UNDER CONSIDERATION HERE, ALTHOUGH IT SHOULD BE NOTED THAT DEVICES INCORPORATING ADDITIONAL AXES OF MOTION (I.E. TRANSLATIONAL MOTION) ARE BECOMING INCREASINGLY POPULAR AMONG MAJOR SYNTHETIC FLIGHT TRAINER USERS.

CARTER, V.L.
TRAINING EFFECTIVENESS STUDY, APPENDIX XV OF FUTURE UNDERGRAD.

LATE PILOT TRAINING SYSTEM STUDY FINAL REPORT, NORTHROP CORP.,
AIRCRAFT DIVISION, N9R 7C-149, HAWTHORNE, CALIFORNIA, MARCH 1971

* ABSTRACT *

THIS APPENDIX DOCUMENTS THE RESULTS OF THE WORK PERFORMED TO DEVELOP EFFECTIVENESS ESTIMATES FOR THE ALTERNATIVE TRAINING ELEMENTS CONSIDERED IN THE UPT SYSTEM MODEL. EFFECTIVENESS ESTIMATES WERE DEVELOPED FOR THREE CLASSES OF TRAINING ELEMENTS CONSIDERED IN THE MODEL: SYNTHETIC FLIGHT TRAINERS, TRAINING AIRCRAFT, AND DYNAMIC OBSERVATION IN BOTH SYNTHETIC FLIGHT TRAINERS AND TRAINING AIRCRAFT. THE DOCUMENTATION FOR EACH OF THESE CLASSES OF TRAINING METHODS CONSISTS OF A DESCRIPTION OF THE METHODS AND RATIONALE USED TO DEVELOP EFFECTIVENESS ESTIMATES, THE RESULTS OF A REVIEW OF THE AVAILABLE EXPERIMENTAL AND EXPERIENTIAL DATA PERTAINING TO EACH METHOD, AND THE RESULTING EFFECTIVENESS ESTIMATES THEMSELVES.

CATREN, R.L.

A NEW APPROACH FOR ESTABLISHING AERODYNAMIC PERFORMANCE OF
FLIGHT TRAINERS.

8TH ATEC/INDUSTRY CONFERENCE PROCEEDINGS, ORLANDO, FL

18-20 NOV, 1975

* ABSTRACT *

THE PURPOSE OF THIS PAPER IS TO DESCRIBE THE APPROACH TAKEN BY THE ARMY ON DEVICE 2B31, THE CH-47 HELICOPTER TRAINER, TO ENSURE THAT THE AERODYNAMIC PERFORMANCE OF THE TRAINING DEVICE SATISFACTORILY DUPLICATES THAT OF THE HELICOPTER. TO THE BEST OF OUR KNOWLEDGE, THIS APPROACH HAS NEVER BEEN TAKEN BEFORE. IT IS A NEW CONCEPT WHICH ACKNOWLEDGES AND ADDRESSES AN OLD PROBLEM: THE LACK OF DOCUMENTED INFORMATION DEFINING AERODYNAMIC PERFORMANCE IN AN ACCURATE, COMPREHENSIVE FASHION.

IT HAS LONG BEEN RECOGNIZED IN THE TWO AREAS OF PERFORMANCE AND FLYING QUALITIES, IN PARTICULAR, THAT HIGH FIDELITY OF SIMULATION IS CRITICAL. FIDELITY IN THESE TWO AREAS HELPS ASSURE ACCEPTANCE OF THE SIMULATOR BY THE TRAINEE, ENABLES LEARNING OF THE REQUISITE PSYCHOMOTOR SKILLS, AND MAXIMIZES THE TRANSFER OF TRAINING.

CHALK, C. R., AND WASSERMAN, R.

AN ASSESSMENT OF THE ROLE OF SIMULATORS IN MILITARY TACTICAL
FLIGHT TRAINING.

CALSPAN CORP.

REPORT AK-597C-F-1 FOR OFFICE OF ASST. SECRETARY OF DEFENSE,
WASHINGTON, D. C.

30 SEP 1976.

* ABSTRACT *

THE OBJECTIVE OF THIS STUDY WAS TO ASSESS THE USE OF SIMULATORS IN MILITARY TACTICAL FLIGHT TRAINING. THE ASSESSMENT WAS MADE ON THE BASIS OF INFORMATION OBTAINED FROM A LITERATURE SURVEY AND A SURVEY OF INDIVIDUALS IN INDUSTRY AND GOVERNMENT AGENCIES WHO ARE KNOWLEDGEABLE ABOUT FLIGHT SIMULATORS, MILITARY TACTICAL FLIGHT TRAINING AND RELATED MATTERS. FORTY SIX ORGANIZATIONS WERE VISITED DURING THE SURVEY. ASSESSMENTS ARE MADE OF THE USE OF SIMULATORS FOR TRAINING THE FOLLOWING FLIGHT PHASES OR TASKS: COCKPIT PROCEDURES, INSTRUMENT FLIGHT, EMERGENCY PROCEDURES, TAKEOFF AND LANDING, FORMATION FLIGHT, AERIAL REFUELING, DYNAMIC FAILURES, GROUND ATTACK, TRAINING OF MANEUVER LIMITS, RECOVERY FROM UNCONTROLLED FLIGHT, AIR COMBAT AND NONPILOT CREW STATIONS. OTHER ASPECTS OF THE USE OF SIMULATORS FOR AIRCREW TRAINING ARE DISCUSSED AND PROBLEM AREAS REQUIRING RESEARCH AND DEVELOPMENT EFFORT ARE IDENTIFIED (F.C., MOTION AND FORCE CUEING).

CHAMBERS, R. M.
OPERATOR PERFORMANCE IN ACCELERATION ENVIRONMENTS.
IN BURNS, N. M., CHAMBERS, R. M., AND HENDLER, E. (EDS.)
UNUSUAL ENVIRONMENTS AND HUMAN BEHAVIOR
COLLIER-MACMILLAN LTD., LONDON, 1963.

* ABSTRACT *

A COMPREHENSIVE TREATMENT OF THE PROBLEMS OF ACCELERATION IS OFFERED. THE EFFECTS OF ACCELERATION STRESS ON MANY DIMENSIONS OF OPERATOR PERFORMANCE ARE THOROUGHLY DISCUSSED. STUDIES CONDUCTED ON THE PROJECT MERCURY ASTRONAUTS ARE REVIEWED, AS ARE A NUMBER OF INVESTIGATIONS ON HAND CONTROLLERS, DISPLAYS, AND RESTRAINT SYSTEMS THAT WERE DESIGNED TO EXTEND MAN'S ACCELERATION TOLERANCE. THE ANALYSIS OF THE RESULTS OF ALL THE STUDIES REVIEWED IS COMPLEMENTED BY THE AUTHOR'S APPRECIATION OF THE PSYCHOLOGICAL FACTORS (PERSONALITY, EMOTIONAL STATE, MOTIVATION) THAT AFFECT PERFORMANCE.

CHAMBERS, R.M. AND FITCHCOCK, L., FR. EFFECTS OF ACCELERATION ON PILOT PERFORMANCE. U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PENNSYLVANIA, INADC-MA-6219, 26 MARCH 1963.

* ABSTRACT *

THIS REPORT ATTEMPTS TO CONSOLIDATE THE FINDINGS OF BOTH PRIOR AND RECENT RESEARCH IN THE AREA OF ACCELERATION EFFECTS UPON PERFORMANCE AND TO RELATE THESE FINDINGS TO BASIC PILOTING BEHAVIORS. THE DECREMENTS IN THE VISUAL, PSYCHOMOTOR RESPONSE AND INTELLECTUAL PROCESSES WHICH HAVE BEEN FOUND TO ACCOMPANY ACCELERATION STRESS ARE QUANTIFIED WHERE POSSIBLE. BOTH TRANSVERSE AND POSITIVE ACCELERATIONS HAVE BEEN SHOWN TO RAISE

THE LEVEL OF CONTRAST REQUIRED FOR VISUAL BRIGHTNESS AND TO REDUCE GENERAL ACUITY AT ACCELERATION LOADS WELL BELOW THOSE WHICH RESULT IN GROSS VISUAL IMPAIRMENT. SIMILAR IMPAIRMENTS IN DISCRIMINATION RESPONSE RATES ARE ALSO DISCUSSED. THE TECHNIQUES THUS FAR USED TO ASSESS HIGHER MENTAL ABILITY UNDER ACCELERATION ARE PRESENTED AS ARE SOME OF THE PROBLEMS WHICH COMPLICATE SUCH MEASUREMENTS. DATA FROM SUCH STUDIES ARE PRESENTED TO ILLUSTRATE THE REDUCTION IN IMMEDIATE MEMORY AND INFORMATION PROCESSING CAPABILITIES OF PILOTS EXPERIENCING BOTH HIGH LEVEL, SHORT TERM AND MODERATE, EXTENDED ACCELERATIONS.

THE KNOWN EFFECTS OF ACCELERATION UPON THE ABILITY OF PILOTS TO FLY, BOTH SIMPLE AND WHOLE-SYSTEM SIMULATIONS ARE CATALOGED WITH SPECIAL ATTENTION GIVEN TO THE WAYS IN WHICH SUCH VARIABLES AS SYSTEM COMPLEXITY, CONTROLLER CONSTRUCTION, RESTRAINT AND LIFE-SUPPORT EQUIPMENTS, AND SUBJECT LEARNING SERVE TO AUGMENT OR REDUCE THESE EFFECTS.

BRIEF INTRODUCTIONS DESCRIBING THE RELEVANT NOMENCLATURE, SIMULATION TECHNIQUES, AND DATA HANDLING PROCESSES PRECEDE THE DISCUSSION OF RESEARCH FINDINGS.

CHAMBERS, R. M., AND NELSON, J. G.
PILOT BIOMEDICAL AND PSYCHOLOGICAL INSTRUMENTATION FOR
MONITORING PERFORMANCE DURING CENTRIFUGE SIMULATIONS OF SPACE
FLIGHT.
NAVAL AIR DEVELOPMENT CENTER REPORT
NADC-MA-6308,
3 OCT 1963.

* ABSTRACT *

THIS REPORT PRESENTS SOME OF THE RESULTS OF RECENT CENTRIFUGE ACCELERATION RESEARCH AND TRAINING PROJECTS IN WHICH THE BIOMEDICAL, PSYCHOPHYSIOLOGICAL, AND PSYCHOLOGICAL PERFORMANCES OF PILOTS WERE MONITORED AND MEASURED. MONITORING AND RECORDING INSTRUMENTATION TECHNIQUES ARE DESCRIBED, AND AN ATTEMPT IS MADE TO IDENTIFY AND QUANTIFY SOME OF THE CAPABILITIES AND LIMITATIONS OF PILOT PERFORMANCE DURING EXPOSURE TO ACCELERATIONS WHICH VARY IN MAGNITUDE, DURATION, DIRECTION, RATE OF ONSET, AND PROFILE COMPLEXITY. APPARATUS AND METHODS ARE PRESENTED AND DISCUSSED FOR MONITORING VISUAL DISTURBANCE, DISCRIMINATION AND RESPONSE BEHAVIOR, COMPLEX SKILL BEHAVIOR, AND AN APPROACH IS MADE TO THE PROBLEM OF MONITORING HIGHER MENTAL FUNCTIONING. THE PILOTS AND OTHER VOLUNTEERS IN THESE TRAINING AND RESEARCH PROGRAMS WERE THE 7 MERCURY ASTRONAUTS, 6 DYNA-SOAR CONSULTANT PILOTS, APPROXIMATELY 35 OTHER TEST PILOTS, AND APPROXIMATELY 40 OTHER MILITARY AND CIVILIAN VOLUNTEERS.

CHAMBERS, W.S., AWAVS: AN ENGINEERING SIMULATOR FOR DESIGN OF VISUAL FLIGHT TRAINING SIMULATORS. AIAA VISUAL AND MOTION SIMULATION CONFERENCE PROCEEDINGS, DAYTON, OH, APR. 26-28, 1976. (ALSO IN J. OF AIRCRAFT, VOL. 14, NO. 11, NOV. 1977).

* ABSTRACT *

THE NAVY AWAVS PROGRAM IS DESIGNED TO IMPROVE VISUAL SYSTEM TECHNOLOGY AND DEFINE HARDWARE PERFORMANCE REQUIREMENTS FOR TRAINING. A DESCRIPTION IS GIVEN OF THE VISUAL SYSTEM HARDWARE CAPABILITIES BEING DEVELOPED FOR THE INITIAL CARRIER TAKEOFF AND LANDING CONFIGURATION OF AWAVS. THE DISPLAY SYSTEM PROVIDES A COMPOSITE IMAGE OF TWO TV CHANNELS. THE BACKGROUND TV CHANNEL IS A LOW-RESOLUTION WIDE-ANGLE DISPLAY OF SKY AND SEASCAPE. THE TARGET TV CHANNEL'S NARROW FIELD OF VIEW PRESENTS A HIGH-RESOLUTION CARRIER IMAGE FOR INSERTION INTO THE DISPLAYED BACKGROUND CHANNEL. EACH CHANNEL INCLUDES HIGH-PERFORMANCE PERSPECTIVE IMAGE GENERATION, DISTORTION CORRECTION, AND VISIBILITY EFFECTS. IN ADDITION TO ESTABLISHING SYSTEM FEASIBILITY, THE SYSTEM'S VARIABILITY WILL PERMIT INVESTIGATION OF THE EFFECTS OF VISUAL SYSTEM PARAMETERS ON PILOT PERFORMANCE IN A SPECIFIC TASK ENVIRONMENT.

THE FLIGHT SIMULATOR IS A NAVY T2C TWIN-ENGINE JET TRAINER SIMILAR TO NAVY TRAINING DEVICE 2F101. IT INCLUDES A SIX-DEGREE-OF-FREEDOM SYNERGISTIC MOTION BASE AND A G-SEAT.

CHANEY, R. E., AND PARKS, D. L.
VISUAL-MOTOR PERFORMANCE DURING WHOLE-BODY VIBRATION.
THE BOEING CO., WICHITA KANSAS
TECHNICAL REPORT 5, D3-3512-5, NOV. 1964.

* ABSTRACT *

SEVEN MALE EMPLOYEES OF THE BOEING COMPANY WERE TESTED IN THE COMPANY'S HUMAN VIBRATION FACILITY TO DETERMINE THE EFFECT OF WHOLE BODY VIBRATION ON VISUAL-MOTOR PERFORMANCE. SIX CONTROLS, A LARGE AND A SMALL KNOB, A HORIZONTAL AND A VERTICAL LEVER, AND A HORIZONTAL AND A VERTICAL THUMBWHEEL WERE USED TO ADJUST A STANDARD 3 INCH DIAL INDICATOR TO A PRESCRIBED SETTING. INDEPENDENT VARIABLES INCLUDED VARIATIONS IN VIBRATION FREQUENCY AND SEVERITY, CONTROL FORCE REQUIREMENTS, AND TASK COMPLEXITY. SPEED AND ACCURACY OF TASK ACCOMPLISHMENT WERE RECORDED FOR EACH CONDITION.

A HIGH WORK LOAD CONDITION, VIBRATION INDEPENDENT OF FREQUENCY AND LEVEL, AND CONTROL FORCE REQUIREMENTS, INDIVIDUALLY AFFECTED THE SPEED AND ACCURACY OF OPERATOR ADJUSTMENT. THE TYPE OF CONTROL USED DID NOT INFLUENCE ACCURACY, AND HAD ONLY MINOR INFLUENCE ON ADJUSTMENT TIME WITH MOUNTING POSITION APPARENTLY PRODUCING THE NOTED DIFFERENCES.

CHATHAM, D.C. : A STUDY OF THE CHARACTERISTICS OF HUMAN PILOT
CONTROL RESPONSE TO SIMULATED AIRCRAFT LATERAL MOTIONS.
NACA 1197, 1954.

* ABSTRACT *

THERE ARE PRESENTED STUDIES OF THE CHARACTERISTICS OF PILOT
ABILITY TO CONTROL DYNAMICALLY UNSTABLE YAWING OSCILLATIONS,
STUDIES OF PILOT CONTROL RESPONSE TO SIMULATED AIRCRAFT YAWING
MOTIONS, AND STUDIES OF THE FEASIBILITY OF REPRESENTING PILOT
CONTROL RESPONSE IN AN ANALYTICAL FORM.

CHRISTENSEN, K. K., AND JOHNSON, L. L.
STUDY TO DETERMINE METHODS OF SIMULATING G EFFECTS.
ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY,
FOR AERONAUTICAL ACCESSORIES RESEARCH LABORATORY,
HEADQUARTERS, AIR MATERIEL COMMAND, WRIGHT-PATTERSON AFB, OH,
WADC TECH. NOTE 58-314, OCT 1958.

* ABSTRACT *

METHODS OF SIMULATING ACCELERATION AND DECELERATION SENSATIONS
IN AIRCRAFT FLIGHT SIMULATORS, WITHOUT PRODUCING ACTUAL
ACCELERATION OR DECELERATION, WERE DETERMINED. SIGNIFICANT
SENSATIONS WERE ASCERTAINED, AND STUDIES WERE CONDUCTED OF
METHODS OF MECHANICALLY INDUCING HEAVINESS AND IMMOBILITY
SENSATIONS, CHEMICALLY INDUCING PHYSIOLOGICAL EFFECTS,
PSYCHOLOGICALLY INDUCING EFFECTS OF ACCELERATION, AND
CONTROLLING THE VARIOUS SIMULATED EFFECTS. SEVERAL DEVICES
THAT MAY INDIRECTLY INDUCE ACCELERATION EFFECTS WERE
INVESTIGATED.

MECHANICAL MEANS OF INDUCING AND CONTROLLING HEAVINESS AND
IMMOBILITY ARE CONSIDERED FEASIBLE, ALTHOUGH ALL DEVICES HAVE A
1-G PRESSURE SENSATION WHICH CANNOT BE ELIMINATED. VISUAL
EFFECTS CAN BE SIMULATED. CHEMICAL SIMULATION DOES NOT APPEAR
SATISFACTORY BECAUSE FUNCTION WITH RESPECT TO G IS LACKING,
ADDED SAFETY PRECAUTIONS ARE NECESSARY, AND DETRIMENTAL EFFECTS
ARE POSSIBLE. A PERIOD OF EXPERIMENTAL DEVELOPMENT WILL BE
NECESSARY TO DETERMINE THE OPTIMUM METHODS AND TO MAKE A FULL
EVALUATION OF THE EFFECTIVENESS OF THE SIMULATED SENSATIONS.
(AUTHORS)

CHU, W.F.N. DYNAMIC RESPONSE OF HUMAN LINEARVECTION. S.M.
THESIS, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, MASSACHU-
SETTS INSTITUTE OF TECHNOLOGY, JANUARY 1976.

* ABSTRACT *

THE FUNCTION OF HUMAN VISUALLY INDUCED SENSATION OF LINEAR MOTION (LINEARVECTION) WAS EXAMINED. THE EXPERIMENTS PERFORMED WERE MAINLY DESIGNED TO INVESTIGATE THE FREQUENCY RESPONSE OF THE HUMAN LINEARVECTION MECHANISM. IT WAS SHOWN THAT BOTH THE GAIN AND PHASE EXHIBITED STEADY DECREASE FOR INCREASING FREQUENCY. ASYMMETRY IN THE RESPONSE WAS ALSO STUDIED. IT WAS SHOWN THAT VISUALLY INDUCED DOWNWARD MOVING SENSATION IS STRONGER THAN THE SENSATION OF UPWARD MOTION. THERE ALSO SEEMED TO BE A STRONGER BACKWARD MOVING SENSATION THAN THE FORWARD ONE. THE BREAK FREQUENCY WAS FOUND TO BE APPROXIMATELY 0.1 HZ.

CLARK, BRANT. VISUAL SPACE PERCEPTION AS INFLUENCED BY UNUSUAL VESTIBULAR STIMULATION. 'HUMAN FACTORS', VOL. 5, JUNE 1963, P. 265-274.
DEPARTMENT OF PSYCHOLOGY, SAN JOSE STATE COLLEGE, SAN JOSE, CA.

* ABSTRACT *

DURING FLIGHT IN AIRCRAFT AND SPACECRAFT, PILOTS ARE REGULARLY SUBJECTED TO UNUSUAL FORCE ENVIRONMENTS. THESE FORCES NOT ONLY INFLUENCE A VARIETY OF PRESSURE-SENSITIVE MECHANISMS BUT, IN PARTICULAR, THEY STIMULATE THE VESTIBULAR MECHANISM OF THE INNER EAR. THE LATTER SOURCE OF INFORMATION REGARDING SPATIAL ORIENTATION MAY BE IN ACCORD WITH INFORMATION FROM DIRECT VISUAL STIMULATION OF IT MAY BE IN CONFLICT WITH IT. IN THE FIRST CASE, VERIDICAL SPACE PERCEPTION MAY BE EXPECTED, WHILE IN THE SECOND THE PERCEPTION IS FREQUENTLY NONVERIDICAL. THIS RESULTS IN CONSTANT ERRORS IN JUDGMENT WITH RESPECT TO MOTION OF VISUAL OBJECTS AND IN THE PILOT'S ESTIMATES OF THE OBJECTS' POSITION. THESE ERRORS, REFERRED TO BY PILOTS AS 'VERTIGO', ARE BELIEVED TO BE OF IMPORTANCE IN PILOTING AIRCRAFT AND SPACECRAFT WHERE THE PILOT'S TASK INVOLVES ACTIONS BASED ON VISUAL SPACE PERCEPTION.

CLARK, B. THRESHOLDS FOR THE PERCEPTION OF ANGULAR ACCELERATION IN MAN. 'AEROSPACE MEDICINE', 1967, 38, 443-450.

* ABSTRACT *

THIS PAPER REVIEWS 25 STUDIES WHICH REPORT STIMULUS THRESHOLDS FOR THE PERCEPTION OF ANGULAR ACCELERATION IN MAN. OF THESE, ONE IS FOR ROLL AND ONE FOR PITCH; ALL OTHERS ARE FOR YAW. THESE REPORTS CONSTITUTE A MISCELLANY OF DEFINITIONS OF THRESHOLD, ROTATION DEVICES AND PSYCHOPHYSICAL METHODS. THE THRESHOLDS REPORTED VARIED BETWEEN 0.035 DEGREES AND 8.2 DEGREES/SEC(2) WITH A MEDIAN OF ABOUT 1 DEGREE/SEC(2). THE RESULTS OF THE EFFECTS OF SEVERAL EXPERIMENTAL VARIABLES ON THRESHOLDS ARE REVIEWED. THE DATA SUPPORT THE NOTION THAT MAN IS EXTREMELY

SENSITIVE TO ANGULAR ACCELERATION, PARTICULARLY UNDER OPTIMUM CONDITIONS. HOWEVER, TWO CRITICAL LIMITATIONS OF THESE STUDIES (I.E., THE SMALL NUMBER OF OBSERVERS STUDIED AND THE LACK OF DIRECT MEASURES OF ANGULAR ACCELERATION) AND THE VARIATION IN METHODOLOGY BETWEEN STUDIES LIMIT THE GENERALIZATIONS FROM THE DATA.

CLARK, B. THE VESTIBULAR SYSTEM. ANNUAL REVIEW OF PSYCHOLOGY, VOL. 21, 1970, 273-306.

* ABSTRACT *

THIS IS THE FIRST REVIEW IN THE ANNUAL REVIEW OF PSYCHOLOGY DEVOTED EXCLUSIVELY TO THE VESTIBULAR SYSTEM. THE TIME SPAN FOR THIS REVIEW COVERED THE PERIOD FROM MID-1965 TO MID-1968. INTEREST IN THE VESTIBULAR SYSTEM INCREASED DURING THIS PERIOD AS A RESULT OF THE DEVELOPMENT OF MANNED SPACE FLIGHT. THE NEW SITUATIONS CONNECTED WITH SPACE FLIGHT (E.G., ZERO GRAVITY, ROTATING SPACE PLATFORMS) HAVE RAISED BOTH PRACTICAL AND THEORETICAL QUESTIONS ABOUT THE FUNCTION OF THE VESTIBULAR SYSTEM IN MAN'S ORIENTATION IN SPACE AND HIS EFFICIENCY WHEN HE IS IN MOTION. THESE TWO PROBLEMS ARE THE CONCERN OF THIS REVIEW.

CLARK, B. PILOT REPORTS OF DISORIENTATION ACROSS 14 YEARS OF FLIGHT. AEROSPACE MEDICINE. 42(7): 708-712. 1971.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO COMPARE RECENT INCIDENTS INVOLVING DISORIENTATION IN FLIGHT REPORTED BY 336 AIR FORCE, ARMY, AND NAVY PILOTS WITH INCIDENTS REPORTED BY 137 PILOTS IN 1956. THE PILOTS REPORTED THEIR EXPERIENCES USING A CHECK LIST AND A WRITTEN DESCRIPTION OF AN EXPERIENCE WITH DISORIENTATION IN THE AIRCRAFT THEY WERE FLYING AT THE TIME. THE LATTER INCLUDED 40 INCIDENTS WHICH OCCURRED IN SUPPORT OF OPERATIONS IN VIETNAM. THE REPORTS OF DISORIENTATION SHOWED A STRIKING SIMILARITY ACROSS TYPES OF AIRCRAFT FLOWN OVER 14 YEARS OF FLYING, AS WELL AS WITH THE INCIDENTS OCCURRING IN VIETNAM. HOWEVER, SOME VARIATION IN REPORTS BETWEEN AIRCRAFT TYPES WAS NOTED. THESE REPORTS OF DISORIENTATION SUGGEST THAT DISORIENTATION IS CURRENTLY EXPERIENCED IN A WIDE VARIETY OF FLIGHT OPERATIONS AND THAT IT WILL CONTINUE TO BE EXPERIENCED BY AIRCRAFT PILOTS.

CLARK, B. AND GRAYBIEL, A. APPARENT ROTATION OF A FIXED TARGET ASSOCIATED WITH LINEAR ACCELERATION IN FLIGHT. AMERICAN JOURNAL OF OPHTHALMOLOGY, VOL 32, NO. 4, APRIL 1949.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE EFFECTS OF LINEAR ACCELERATION AND DECELERATION ON THE VISUAL PERCEPTION OF A TARGET IN THE DARK. THREE SUBJECTS OBSERVED A COLLIMATED 'STAR' IN THE DARK WHILE THE PILOT OF AN SNJ-6 AIRCRAFT EXECUTED VARIOUS DEGREES OF LINEAR ACCELERATION. THE SUBJECTS GAVE A RUNNING ACCOUNT OF THE BEHAVIOR OF THE STAR USING A THERAT MICROPHONE CONNECTED TO A WIRE RECORDER.

THE FORCES PRODUCED REPRESENTED THE RANGE OF ACCELERATIONS AND DECELERATIONS OCCURRING IN THE NORMAL OPERATION OF THE AIRCRAFT. THE FORCES WERE MEASURED BY A THREE COMPONENT ACCELEROMETER WHICH SHOWED THAT ACCELERATIVE AND DECELERATIVE FORCES BUILT UP TO A MAXIMUM IN APPROXIMATELY 5.5 SECONDS AND WITHIN 2 TO 3 SECONDS BEGAN TO DROP OFF SLOWLY TO ZERO.

NET RESULT OF THESE ACCELERATIONS AND DECELERATIONS WAS TO CHANGE BOTH THE MAGNITUDE AND THE DIRECTION OF THE RESULTANT FORCE ACTING ON THE SUBJECT. THE MAGNITUDE OF THE MAXIMUM RESULTANT FORCES VARIED BETWEEN 1.0004G AND 1.0925G AND ITS CHANGE IN DIRECTION VARIED BETWEEN 1.7 DEGREES AND 23.7 DEGREES

WHEN THE SUBJECTS FACED TO THE LEFT IN THE AIRCRAFT, THE RADIATING LINES OF THE STAR APPEARED TO ROTATE ABOUT THE CENTRAL POINT TO A NEW POSITION. THIS ROTATION WAS CLOCKWISE DURING DECELERATION AND COUNTERCLOCKWISE DURING ACCELERATION. AS THE FORCE BECAME SMALLER, THE STAR APPEARED TO ROTATE BACK TO ITS NORMAL POSITION. THIS ILLUSORY ROTATION OCCURRED AT ALL STIMULUS LEVELS.

THE THRESHOLDS OF LINEAR DECELERATION FOR MOTION AND DISPLACEMENT WERE 0.067G AND 0.078G RESPECTIVELY. ALL OF THE LINEAR ACCELERATIONS USED WERE ABOVE THRESHOLD. THE MEAN MAXIMUM ROTATION DURING DECELERATION INCREASED AS THE DECELERATIVE FORCE INCREASED, THE MAXIMUM ESTIMATED ROTATION REPORTED BEING 15 DEGREES.

THERE WAS ALSO A POSITIVE RELATION BETWEEN THE MAXIMUM FORCE AND THE DURATION OF THE ILLUSORY EFFECT. THE ACCELERATIVE EFFECTS DID NOT SHOW A CONSISTENT VARIATION WITH THE MAXIMUM CHANGE IN THE ACCELERATIVE FORCE. THE RESULTS ARE SIMILAR TO THOSE OBSERVED ON A HUMAN CENTRIFUGE AND SHOW THAT LINEAR ACCELERATION AND DECELERATION DURING FLIGHT HAVE A MARKED INFLUENCE UPON VISUAL PERCEPTION IN THE DARK. ALTHOUGH THE OBSERVED ROTATIONS WERE SMALL, THEY WERE CLEARLY DEFINED AND MAY BE CONSIDERED TO BE FACTORS CONTRIBUTING TO DISORIENTATION IN FILTS.

CLARK, R. AND GRAYPIEL, A. ILLUSORY PERCEPTION OF ROTATION FOLLOWING CONSTANT TURNS IN A LINK TRAINER. REPORT NM 001 059.01.31, NAVAL SCHOOL OF AVIATION MEDICINE, 15 AUGUST 1952

* ABSTRACT *

THIS INVESTIGATION WAS DESIGNED TO STUDY THE DURATION OF ILLUSORY PERCEPTION OF ROTATION FOLLOWING CONSTANT TURNS IN A LINK TRAINER. THE SUBJECTS WERE TURNED IN A LINK TRAINER AT 10 RPM IN A COMPLETELY DARK ROOM USING SIX DIFFERENT INTERVALS OF CONSTANT TURN. THIRTY-ONE FLIGHT STUDENTS REPORTED THEIR PERCEPTION OF ROTATION BOTH DURING AND FOLLOWING THE TURNS. THE MAXIMUM ILLUSORY EFFECTS OCCURRED WHEN THE CONSTANT TURN WAS HELD FOR A RELATIVELY PROLONGED PERIOD OF TIME. THE DURATION OF THE ILLUSION INCREASED SHARPLY AS THE PERIOD OF CONSTANT TURN INCREASED UP TO APPROXIMATELY 30 SECONDS, AND THEREAFTER, INCREASED SLOWLY UP TO 60 SECONDS WITH A SLIGHT INCREASE EVIDENT UP TO TWO MINUTES. IN MOST CASES THE ILLUSORY EFFECTS WERE NOT OBSERVED WHEN THE PERIOD OF CONSTANT TURN WAS NEAR ZERO. THESE RESULTS SHOW THAT PILOTS WHO HOLD PROLONGED CONSTANT SPEED TURNS IN AN AIRCRAFT WITHOUT ADEQUATE VISUAL ORIENTATION ARE PARTICULARLY SUSCEPTIBLE TO ILLUSORY PERCEPTIONS OF ROTATION. THESE ILLUSORY EFFECTS CAN BE EXPECTED IN NORMAL NAVAL AVIATORS AND THEY SHOULD BE MADE FAMILIAR WITH THE FACT THAT SUCH ILLUSORY PERCEPTIONS ARE NORMAL AND MAY BE EXPECTED FOLLOWING PROLONGED CONSTANT SPEED TURNS IN FLIGHT.

CLARK, B. AND GRAYBIEL, A. FACTORS CONTRIBUTING TO THE DELAY IN THE PERCEPTION OF THE OCULOGRATIC ILLUSION. 'AMERICAN JOURNAL OF PSYCHOLOGY', VOL. 79, SEPT. 1966.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO OBSERVE THE EFFECTS OF FACTORS WHICH CONTRIBUTE TO THE DELAY IN THE CHANGE IN THE PERCEPTION OF THE HORIZONTAL FOLLOWING A CHANGE IN THE DIRECTION OF RESULTANT FORCE ACTING ON A SUBJECT (THE OCULOGRATIC ILLUSION). FIVE NORMAL AND EIGHT LABYRINTHINE DEFECTIVE MEN WERE STUDIED IN A SLOW ROTATION ROOM. FOUR SEPARATE EXPERIMENTS WERE CONDUCTED WITH CHANGES IN DIRECTION OF RESULTANT FORCE OF 20 DEGREES OR 30 DEGREES ACTING ON THE SUBJECTS. THE RESULTS SHOWED VERY SMALL EFFECTS OF PREEXPOSURE-CONDITIONS PRIOR TO THE CHANGE IN DIRECTION OF RESULTANT FORCE. ON THE OTHER HAND, DELAYS IN THE PRESENTATION OF A LUMINOUS TARGET FOLLOWING A CHANGE IN THE RESULTANT FORCE AND BEFORE SETTINGS TO THE VISUAL HORIZONTAL OCCURRED PRODUCED MAJOR, SYSTEMATIC EFFECTS ON THE PERCEPTION OF THE VISUAL HORIZONTAL. THESE RESULTS ARE DISCUSSED IN TERMS OF THE INTERACTION OF VISUAL AND GRAVITATIONAL CUES IN PRODUCING THE LAG-EFFECT.

CLARK, B. AND GRAYBIEL, A. INFLUENCE OF CONTACT CUES ON THE PERCEPTION OF THE OCULOGRATIC ILLUSION. 'ACTA OTO-LARYNGOLOGICA' 45, 373-380, 1968.

AD-A061 687 NAVAL TRAINING EQUIPMENT CENTER ORLANDO FLA
MOTION IN FLIGHT SIMULATION: AN ANNOTATED BIBLIOGRAPHY. (U)
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* ABSTRACT *

MEASUREMENTS WERE MADE ON FIVE NORMAL AND FIVE LABYRINTHINE-DEFECTIVE MEN WHEN THEY STOOD ERECT IN A ROOM WHILE IT WAS STATIONARY AND AGAIN WHEN IT WAS ROTATING. THE PROCEDURE WAS DESIGNED TO PRODUCE TWO SITUATIONS FOR THE NORMAL MEN IN WHICH STATOLITH AND NOSTOLITH INFORMATION WERE SYNERGISTIC AND THREE OTHERS IN WHICH THEY WERE ANTAGONISTIC. PERCEPTION OF THE VISUAL HORIZONTAL DURING ROTATION WAS NOT SYSTEMATICALLY RELATED TO DIFFERENCES IN HEAD AND BODY POSITION NOR WERE THERE SIGNIFICANT DIFFERENCES BETWEEN THE NORMAL AND L-D MEN. THE RESULTS SHOW THAT NOSTOLITH INFORMATION PREDOMINATES IN THIS EXPERIMENTAL SITUATION.

CLARK, B. AND MACCORQUODALE, K. THE EFFECTS OF REPEATED ROTARY ACCELERATION ON THE OCULO-GYRAL ILLUSION. JOURNAL OF EXPERIMENTAL PSYCHOLOGY, VOL 39, NO. 2, PP. 219-227, APRIL 1949.

* ABSTRACT *

THE EFFECTS OF REPEATED ANGULAR ACCELERATION AND DECELERATION ON VISUAL PERCEPTION WERE STUDIED IN THREE SUBJECTS TO ESTABLISH WHETHER ANY CHANGE IN THE OCULO-GYRAL ILLUSION WOULD OCCUR. THE SUBJECTS WERE ROTATED WHILE THEY SAT IN A LINK TRAINER WHICH ROTATED ONLY ABOUT A VERTICAL AXIS. THE SUBJECTS WERE TURNED FOR 10 SUCCESSIVE TRIALS AT THREE RPM AND THEN FOR 10 SUCCESSIVE TRIALS AT 20 RPM ON 10 SUCCESSIVE DAYS. ON THE FOLLOWING FOUR DAYS THE SUBJECTS TOOK 19 SUCCESSIVE TRIALS AT 20 RPM. MEASURES OF THE ANGULAR ACCELERATIONS AND DECELERATION WERE AVAILABLE AT THE SLOWER ROTATION SPEEDS. THE SUBJECTS OBSERVED A COMPLEX TARGET IN THE DARK AND REPORTED THE ONSET AND OFFSET OF THE OCULO-GYRAL ILLUSION FOLLOWING BOTH ACCELERATION AND DECELERATION FOR EACH TRIAL. THE DURATION OF THE EFFECTS WAS RECORDED IN AN ADJACENT ROOM BY THE EXPERIMENTER. THE THREE SUBJECTS WERE FAMILIAR WITH THE EFFECTS OBSERVED, BUT THEY HAD NOT BEEN ROTATED FOR APPROXIMATELY ONE YEAR, SO THEY WERE SUITABLE FOR A STUDY OF HABITUATION.

NO EVIDENCE OF HABITUATION WAS FOUND FOR ANY OF THE EFFECTS OBSERVED. IMMEDIATELY FOLLOWING ACCELERATION AND DECELERATION THE SUBJECTS REPORTED APPARENT MOTION OF THE TARGET (OCULO-GYRAL ILLUSION, FIRST EFFECT). THEY ALSO REPORTED A REVERSAL OF THIS MOTION WHEN THE FIRST EFFECT ENDED; ON SOME TRIALS, ONE SUBJECT REPORTED A THIRD EFFECT OF BRIEF DURATION FOLLOWING THE SECOND EFFECT. A DETAILED ANALYSIS OF THE THREE EFFECTS SHOWED NO HABITUATION FOR ANY ONE OF THEM NOR FOR THE TOTAL DURATION OF THE APPARENT MOTION. THE RESULTS ALSO SUPPORT THE HYPOTHESIS THAT THE NYSTAGMUS REMAINED UNCHANGED. ALTHOUGH THIS STUDY DOES NOT PRECLUDE THE POSSIBILITY OF HABITUATION OF THE OCULO-GYRAL ILLUSION UNDER OTHER CONDITIONS, IT IS CLEAR THAT HABITUATION DOES NOT NECESSARILY FOLLOW A SERIES OF STRONG ROTARY ACCELERATIONS AND DECELERATIONS.

CLARK, B. AND NICHOLSON, M.A. AVIATOR'S VERTIGO: A CAUSE OF
PILOT ERROR IN NAVAL AVIATION STUDENTS. JOURNAL OF AVIATION
MEDICINE, 25: 171/179, 1954

* ABSTRACT *

A QUESTIONNAIRE CONCERNING STUDENT PILOTS EXPERIENCES WITH
DISORIENTATION WAS ADMINISTERED TO 226 BASIC STUDENTS AND 276
ADVANCED STUDENTS IN THE NAVAL AIR TRAINING COMMAND. THE FIRST
PART OF THE QUESTIONNAIRE ASKED THE STUDENTS TO WRITE
DESCRIPTIONS OF SPECIFIC FLIGHT EXPERIENCES, WHILE THE SECOND
PART OF THE QUESTIONNAIRE CONSISTED OF A CHECK LIST OF PILOTS'
EXPERIENCES WITH DISORIENTATION. THE WRITTEN DESCRIPTIONS
AFFORDED DETAILED INFORMATION REGARDING TYPES OF VERTIGO
EXPERIENCED BY FLIGHT STUDENTS, BUT THE MAJOR ANALYSIS WAS
BASED ON THE RESPONSES TO THE CHECK LIST. IN THIS ANALYSIS, IT
WAS FOUND THAT EVERY VERTIGO ITEM WAS MARKED BY AT LEAST ONE
STUDENT. THE ITEM MARKED BY THE GREATEST NUMBER OF STUDENTS
(62 PER CENT) WAS ...THERE WAS AN APPARENT TURNING WHEN THE
INSTRUMENTS INDICATED STRAIGHT AND LEVEL. THE MEAN NUMBER OF
ITEMS MARKED BY BASIC STUDENTS WAS 9.26 AND THE MEAN NUMBER
MARKED BY ADVANCED STUDENTS WAS 13.86. ALTHOUGH 4 PER CENT OF
THE BASIC STUDENTS MARKED NO ITEMS, ALL OF THE ADVANCED
STUDENTS REPORTED AT LEAST ONE EXPERIENCE WITH VERTIGO AND
16 PER CENT OF THE STUDENTS IN THE TOTAL GROUP MARKED TWENTY
ITEMS OR MORE.

THE DATA REVEALED THAT THE MOST COMMON TYPE OF VERTIGO
EXPERIENCED BY STUDENT PILOTS INVOLVED CONFUSIONS WITH REGARD
TO ATTITUDE AND POSITION OF THE AIRCRAFT, ALTHOUGH CONFUSIONS
WITH REGARD TO VISUAL PERCEPTION WERE COMMON. THESE DATA ARE
CONVINCING EVIDENCE THAT VERTIGO IS EXPERIENCED SOONER OR LATER
BY STUDENT PILOTS IN THEIR TRAINING AND THAT THERE IS A CLOSE
RELATIONSHIP BETWEEN VERTIGO AND AVIATION SAFETY.

CLARK, B. AND STEWART, J.D. PERCEPTION OF ANGULAR ACCELERATION
ABOUT THE YAW AXIS OF A FLIGHT SIMULATOR: THRESHOLDS AND REAC-
TION LATENCY FOR RESEARCH PILOTS. 'AEROSPACE MEDICINE', 1962,
33:1426-1432.

* ABSTRACT *

THRESHOLDS FOR THE PERCEPTION OF ANGULAR ACCELERATION AND
REACTION LATENCIES FOR ACCELERATIONS IN THE REGION OF THE
THRESHOLD WERE DETERMINED ON THE AMES THREE-DEGREES-OF-FREEDOM
SIMULATOR. THIS SIMULATOR WAS CONTROLLED BY AN ANALOG COMPUTER
SIGNAL AND EACH ANGULAR ACCELERATION WAS MEASURED THROUGHOUT
ITS 10 SECOND DURATION BY AN ANGULAR ACCELEROMETER. A FORCED
CHOICE PROCEDURE WAS USED, THE SUBJECT BEING REQUIRED TO REPORT
THE DIRECTION OF ROTATION ON EACH TRIAL. FIVE SUBJECTS,

INCLUDING THREE RESEARCH PILOTS, WHO HAD HAD CONSIDERABLE EXPERIENCE IN AIRCRAFT AND IN ROTATING DEVICES WERE STUDIED. THRESHOLDS WERE DETERMINED FROM PLOTS OF THE PER CENT CORRECT RESPONSE AT EACH STIMULUS LEVEL. THE THRESHOLD DEFINED AS THE LEVEL OF 75 PER CENT CORRECT RESPONSE, RANGED FROM 0.12 DEG. TO 0.17 DEG./SEC(2), THE THRESHOLDS FOR THE RESEARCH PILOTS BEING VERY CLOSE TO THE THRESHOLDS OF THE OTHER SUBJECTS. REACTION LATENCIES WERE FOUND TO VARY INVERSELY WITH THE ANGULAR ACCELERATION, AND THE LATENCY AT THRESHOLD VALUES VARIED FROM 7.2 TO 11.9 SECONDS. AT ANGULAR ACCELERATIONS OF 0.6 DEGREES/SEC(2) WHERE ALL SUBJECTS REPORTED WITHOUT ERROR, THE MEAN REACTION LATENCIES VARIED BETWEEN 3.1 AND 6.2 SECONDS WHILE IN THE REGION OF 10 DEGREES/SEC(2) THE REACTION LATENCY VARIED FROM 0.5 TO 1.0 SECOND.

CLARK, B. AND STEWART, J.D. VESTIBULAR AND NONVESTIBULAR INFORMATION IN JUDGMENTS OF ATTITUDE AND CORIOLIS MOTION IN A PILOTTED FLIGHT SIMULATOR. AEROSPACE MEDICINE, SEPT. 1967, 936-940

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO INVESTIGATE THE MODULATION OF VESTIBULAR RESPONSES BY TACTUAL AND PROPRIOCEPTIVE STIMULI IN THE PERCEPTION OF MOTION AND COCKPIT ATTITUDE IN A ROTATING FLIGHT SIMULATOR. EIGHT OBSERVERS WERE ROTATED IN THE COCKPIT OF THE AMES FIVE-DEGREE-OF-FREEDOM SIMULATOR 30 FEET FROM THE CENTER OF ROTATION. DURING THE ROTATION, THE COCKPIT OR THE HEAD AND BODY WAS PITCHED 35 DEGREES OR 70 DEGREES TO PRODUCE CORIOLIS ACCELERATIONS. HEAD NODDING WAS ALSO STUDIED. THE REPORTED CORIOLIS ROTATIONS WERE VERY SIMILAR FOR THE THREE METHODS OF PRODUCING HEAD MOTION, AND IT WAS CONCLUDED THAT CORIOLIS ROTATION IN THIS SITUATION WAS NOT MODULATED IN ANY SIGNIFICANT WAY BY THE OTHER SENSORY INFORMATION AVAILABLE TO THE OBSERVERS. ON THE OTHER HAND, THE ESTIMATES OF THE ATTITUDE OF THE COCKPIT WHILE THE HEAD AND BODY PITCHED DOWN WERE VERY SIMILAR TO THOSE WHEN THE BODY WAS PITCHED UP. FOR BOTH CONDITIONS, THE ESTIMATES OF COCKPIT ATTITUDE INDICATED THAT THE NOSE OF THE COCKPIT WAS JUDGED TO BE LOWER THAN ITS DEVIATION FROM THE RESULTANT FORCE DURING ROTATION AT THE LOWER VELOCITIES, WHILE AT 12 RPM THE ESTIMATES WERE QUITE VERIDICAL. THE DATA SUGGEST, THEREFORE, THAT THE ESTIMATES OF ATTITUDE ARE DEPENDENT UPON TACTUAL AND PROPRIOCEPTIVE INFORMATION AS WELL AS UPON INFORMATION FROM THE VESTIBULAR MECHANISM.

CLARK, B. AND STEWARD, J.D. MAGNITUDE ESTIMATES OF ROTATIONAL VELOCITY DURING AND FOLLOWING PROLONGED INCREASING, CONSTANT, AND ZERO ANGULAR ACCELERATION. JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 1968, VOL. 78, NO. 2, 329-339

* ABSTRACT *

VELOCITY OF ROTATION WAS OBSERVED BY 10 SUBJECTS IN A ROTATING SIMULATOR DURING AND FOLLOWING ACCELERATIONS ABOUT A VERTICAL AXIS WHICH VARIED BETWEEN .5 DEGREES - 1.5 DEGREES PER SECOND SQUARED AND .006 DEGREES - .030 DEGREES PER SECOND CUBED AND CONTINUED FOR 2-3 MIN. TRIALS WITH 0 ACCELERATION WERE ALSO INCLUDED. MAGNITUDE ESTIMATES OF VELOCITY OF ROTATION INCREASED AND THEN DECLINED DURING THE CONSTANT ACCELERATIONS, WHILE MORE COMPLEX EFFECTS OCCURRED DURING INCREASING ACCELERATIONS. AFTER-EFFECTS AND AN AUTOKINETIC EFFECT WERE ALSO OBSERVED. CURRENT THEORY OF VESTIBULAR FUNCTION IS CONSIDERED IN THE LIGHT OF THESE RESULTS.

CLARK, B. AND STEWART, J.D. COMPARISON OF THREE METHODS TO DETERMINE THRESHOLDS FOR PERCEPTION OF ANGULAR ACCELERATION., THE 'AMERICAN J. OF PSYCHOLOGY', 1968, VOL. LXXXI, 207-216.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO COMPARE THREE PSYCHOPHYSICAL METHODS USED TO DETERMINE THRESHOLDS FOR THE PERCEPTION OF ANGULAR ACCELERATION IN MAN. SIXTEEN MEN WITH NORMAL VESTIBULAR FUNCTION WERE STUDIED USING THREE RANDOM FORCED-CHOICE PROCEDURES WITH A SIMULATOR ROTATING SUBJECT ABOUT A VERTICAL AXIS. THE CONSTANT METHOD, USING A 10-SEC. CONSTANT ACCELERATION, WAS FOUND TO BE THE MOST RELIABLE, AND THERE WAS A HIGH CORRELATION BETWEEN THRESHOLDS DETERMINED BY A FORCED-CHOICE RANDOM DOUBLE-STAIRCASE METHOD AND THE CONSTANT METHOD. THE CONSTANTLY INCREASING ACCELERATIONS OF THE RAMP METHOD WERE FOUND TO PRODUCE UNRELIABLE, ECUIVOCAL RESULTS. THE THRESHOLDS DETERMINED BY THE CONSTANT AND STAIRCASE METHODS FOR 16 SUBJECTS VARIED BETWEEN 0.07 DEGREES AND 1.19 DEGREES PER SECOND CUBED.

CLARK, B. AND STEWART, J.D. COMPARISON OF SENSITIVITY FOR THE PERCEPTION OF BODILY ROTATION AND THE OCULOGYRAL ILLUSION. 'PERCEPTION AND PSYCHOPHYSICS.', 1968, VOL. 3 (4A).

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO COMPARE THE SENSITIVITY OF HUMANS TO ANGULAR ACCELERATION USING THE PERCEPTION OF ROTATION AND THE PERCEPTION OF THE OCULOGYRAL ILLUSION AS TWO INDICATORS. TEN MEN WITH NORMAL VESTIBULAR FUNCTIONS WERE STUDIED IN A PRECISION ROTATION DEVICE USING A RANDOM, FORCED CHOICE, DOUBLE STAIRCASE METHOD TO DETERMINE THE THRESHOLDS. THE THRESHOLDS FOR THE OCULOGYRAL ILLUSION WERE FOUND TO BE SUBSTANTIALLY AND SIGNIFICANTLY LOWER THAN THRESHOLDS FOR THE PERCEPTION OF ROTATION. THE IMPLICATIONS OF THESE FINDINGS FOR AN UNDERSTANDING OF THE OCULOGYRAL ILLUSION ARE DISCUSSED.

CLARK, B. AND STEWART, J.D. THRESHOLDS FOR THE PERCEPTION OF ANGULAR ACCELERATION DETERMINED IN A PRECISION ROTATION DEVICE. A PAPER PRESENTED AT MEETING OF THE AEROSPACE MEDICAL ASSOCIATION, MIAMI BEACH, FLORIDA, MAY 6-9, 1968.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE SENSITIVITY OF NORMAL HUMAN OBSERVERS TO ANGULAR ACCELERATION ABOUT THEIR YAW AXIS. THE DATA WERE OBTAINED FOR 33 NORMAL MEN USING A ONE-DEGREE-OF-FREEDOM SIMULATOR WHICH COULD PRODUCE ANGULAR ACCELERATIONS WITH NARROW LIMITS OF ERROR. A FORCED-CHOICE, RANDOM, DOUBLE STAIRCASE METHOD WAS USED TO PRESENT THE STIMULI. THRESHOLDS FOR THE PERCEPTION OF ROTATION FOR THESE 33 MEN WERE FOUND TO VARY BETWEEN 0.05 DEGREES TO 2.2 DEGREES PER SECOND SQUARED WITH A MEAN OF 0.42 DEGREES PER SECOND SQUARED (S.D. 0.40 DEGREES PER SECOND SQUARED) AND A MEDIAN OF 0.29 DEGREES PER SECOND SQUARED. THESE DATA INDICATE THAT NORMAL MEN HAVE EXTREMELY HIGH SENSITIVITY TO ANGULAR ACCELERATION ABOUT THEIR YAW AXIS UNDER OPTIMUM TESTING CONDITIONS.

CLARK, B. AND STEWART, J.D. THRESHOLDS FOR THE PERCEPTION OF ANGULAR ACCELERATION ABOUT THE THREE MAJOR BODY AXES. 'ACTA OTOLARYNG' 69:231-238, 1970.

* ABSTRACT *

THIS REPORT PRESENTS TWO EXPERIMENTS CONCERNED WITH MAN'S SENSITIVITY TO ANGULAR ACCELERATION ABOUT HIS THREE MAJOR BODY AXES. THE PURPOSE OF THE STUDY WAS TO DETERMINE THRESHOLDS FOR ACCELERATIONS ABOUT THE X, Y, AND Z AXES. THE THRESHOLDS OF 22 NORMAL MEN WERE ESTABLISHED FOR THE THREE AXES USING A PRECISION ROTATION DEVICE. THE ANGULAR ACCELERATIONS WERE ORDERED USING A RANDOM, FORCED CHOICE, DOUBLE-STAIRCASE PROCEDURE. IT WAS FOUND THAT MEAN THRESHOLDS FOR THE THREE AXES WERE NOT SIGNIFICANTLY DIFFERENT AND THAT FOR EACH OF THE THREE AXES THE RANGE OF INDIVIDUAL THRESHOLDS WAS SUBSTANTIAL. INTERCORRELATIONS AMONG THE THREE THRESHOLDS WERE NOT SIGNIFICANTLY DIFFERENT FROM ZERO. IT WAS CONCLUDED THAT, UNDER OPTIMUM TESTING CONDITIONS, THE MEAN THRESHOLDS FOR ROTATION ABOUT THE THREE MAJOR BODY AXES ARE ESSENTIALLY THE SAME, BUT THAT THE THRESHOLD ABOUT ANY ONE BODY AXIS DOES NOT PREDICT THE THRESHOLD ABOUT THE OTHER TWO.

CLARK, B. AND STEWART, J.D. COMPARISON OF THE SENSITIVITY TO ROTATION OF PILOTS AND NONPILOTS. AEROSPACE MEDICINE, VOL. 43 (1), PP. 8-12, 1972.

* ABSTRACT *

THIRTY-SIX AIRLINE PILOTS AND 56 NONPILOTS WERE TESTED TO DETERMINE THEIR SENSITIVITY TO ROTATION. A STAIRCASE PROCEDURE WAS USED TO DETERMINE OCULOGYRAL ILLUSION AND PERCEPTION OF ROTATION THRESHOLDS IN A PRECISION ROTATION DEVICE. THE RESULTS INDICATED THAT (1) THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN THE TWO GROUPS FOR EITHER THRESHOLD MEASURE, (2) THE THRESHOLDS FOR THE OCULOGYRAL ILLUSION WERE SIGNIFICANTLY LOWER THAN THE PERCEPTION OF ROTATION THRESHOLDS FOR BOTH GROUPS, AND (3) CHANGES IN THRESHOLD AS A FUNCTION OF AGE WERE MINIMAL FOR 91 OF THE MEN. THE VALIDITY AND RESULTS OF THE TESTS ARE DISCUSSED WITH REGARD TO THE PILOT'S USE OF MOTION INFORMATION IN CONTROL TASKS FOR AIRCRAFT AND SIMULATORS.

CLARK, B. AND STEWART, J.D. RELATIONSHIP BETWEEN MOTION SICKNESS EXPERIENCE AND TESTS OF THE PERCEPTION OF ROTATION IN PILOTS AND NONPILOTS. 'AEROSPACE MEDICINE', VOL. 44, '4', APRIL 1973, 393-396

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO COMPARE FIVE SUBJECTIVE TESTS OF VESTIBULAR FUNCTION WITH REPORTS OF MOTION SICKNESS EXPERIENCE. DATA ON MOTION SICKNESS EXPERIENCE AND VESTIBULAR TEST RESULTS WERE OBTAINED FROM 35 PILOTS AND 51 NONPILOTS. REPORTS OF MOTION SICKNESS EXPERIENCE WERE ALSO OBTAINED FROM 122 MEN AND 149 WOMEN AT CALIFORNIA STATE UNIVERSITY, SAN JOSE. THE RESULTS REVEALED THAT PILOTS REPORTED SIGNIFICANTLY LESS MOTION SICKNESS THAN THE THREE GROUPS OF NONPILOTS. THREE MEASURES OF THRESHOLDS FOR THE PERCEPTION OF ROTATION SHOWED VERY LOW AND NONSIGNIFICANT CORRELATIONS WITH REPORTS OF MOTION SICKNESS. OF THE THREE CUPULOMETRIC SLOPES OBTAINED ABOUT THE THREE MAJOR BODY AXES, ONLY THAT FOR THE Z AXIS SHOWED A SIGNIFICANT CORRELATION WITH MOTION SICKNESS. EXPONENTS FOR THE POWER LAWS FOR THE PERCEPTION OF ROTATION SHOWED NONSIGNIFICANT CORRELATIONS WITH MOTION SICKNESS. THE DATA SUGGEST THAT THRESHOLD MEASURES HAVE NO VALUE IN PREDICTING AND UNDERSTANDING MOTION SICKNESS. ON THE OTHER HAND, TESTS THAT GIVE SOME INDICATION OF CENTRAL NERVOUS SYSTEM PROCESSING OF VESTIBULAR INPUTS HAVE THE GREATEST PROMISE OF REVEALING SIGNIFICANT FINDINGS RELATED TO THE CAUSES OF MOTION SICKNESS.

CLARK, C. C. NAVY CENTRIFUGE SIMULATION OF LOW ALTITUDE FLIGHT OF THE A2F, PROGRAM 1. AVIATION MEDICAL ACCELERATION LABORATORY, U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PENNSYLVANIA, NADC-PA-L6005, 29 MARCH 1960.

* ABSTRACT *

ON 24 NOVEMBER 1959, A CONFERENCE WAS HELD AT THE BUREAU OF AERONAUTICS UNDER THE DIRECTION OF CAPTAIN W. L. JONES. ITS

PURPOSE WAS TO REVIEW THE RESULTS OF THE A2F CENTRIFUGE PROGRAM RECENTLY COMPLETED ON THE NAVY HUMAN CENTRIFUGE AT JOHNSVILLE, AND TO PLAN THE NEXT STEPS TO DETERMINE THE NEED FOR A GUST ALLEVIATION SYSTEM FOR THE A2F IN ORDER FOR THE CREW TO COMPLETE PROPOSED LOW ALTITUDE, HIGH SPEED PENETRATION MISSIONS. IT WAS DESIRED, IF POSSIBLE, TO DETERMINE BY COMPUTER AND HUMAN MOTION SIMULATOR STUDIES PRIOR TO FLIGHT OF THE A2F WHETHER OR NOT GUST ALLEVIATION IS NEEDED.

CLARK, C.C. ACCELERATION AND BODY DISTORTION. IN BENNETT, E., DEGAN, J. AND SPIEGAL, J. (EDS). 'HUMAN FACTORS IN TECHNOLOGY'. HUMAN FACTORS SOCIETY, MCGRAW-HILL: NEW YORK, 1963.

* ABSTRACT *

THIS CHAPTER DESCRIBED STUDIES CONDUCTED ON THE JOHNSVILLE NAVY CENTRIFUGE WHILE THE AUTHOR WAS WITH THE BIOPHYSICS AND BIOMEDICAL DIVISION OF THE AVIATION MEDICAL ACCELERATION LABORATORY, NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PENNSYLVANIA.

A CONSISTENT PHYSIOLOGICAL-ACCELERATION TERMINOLOGY WAS SUMMARIZED AND METHODS OF ACCELERATION PROTECTION WERE DISCUSSED.

CLARK, C.C. 'HUMAN CONTROL PERFORMANCE AND TOLERANCE UNDER SEVERE COMPLEX WAVEFORM VIBRATION WITH A PRELIMINARY HISTORICAL REVIEW OF FLIGHT SIMULATION.' MARTIN-BALTIMORE ER 12838, FEBRUARY 1963.

* ABSTRACT *

PROBLEMS OF TERMINOLOGY OF ACCELERATION AND FLIGHT SIMULATION ARE REVIEWED WITH A PRELIMINARY HISTORICAL REVIEW OF PARTICULARLY MOVING BASE FLIGHT SIMULATION. THE CAPABILITIES AND LIMITATIONS OF THE NAVY JOHNSVILLE HUMAN CENTRIFUGE AND THE NORTH AMERICAN AVIATION (COLUMBUS) G-SEAT FOR HOSTILE SIMULATION ARE PRESENTED; THE LATTER IS MORE REALISTIC.

FOR HOSTILE ACCELERATION POWER SPECTRA PEAKING NEAR 1 CPS, LIMITED FLIGHT CONTROL COULD BE MAINTAINED AT A HOSTILE LEVEL OF 0.35 GZ RMS, EQUIVALENT TO AIRCRAFT RESPONSE TO VERY SEVERE TURBULENCE, WITH PANEL ACCELEROMETER READINGS BETWEEN 1.2 AND 4.0 GZ MAINTAINED FOR 30 MINUTES. A HOSTILE OF 0.70 GZ RMS, WITH PANEL ACCELEROMETER READINGS BETWEEN 3 AND 5.5 GZ COULD BE TOLERATED FOR AT LEAST 100 SECONDS. ALTHOUGH WITH SEVERE BUT FAR FROM COMPLETE CONTROL LOSS. FOR THESE HOSTILE CONDITIONS, TOLERANCE WAS FATIGUE LIMITED, DUE TO MUSCULAR EFFORTS TO STAY IN THE COCKPIT. THE TORSO RESTRAINT IS INADEQUATE FOR HOSTILE CONDITIONS CONSIDERABLY MORE SEVERE THAN THOSE EXPERIENCED IN

PRESSENT AIRCRAFT.

POTENTIAL DEVELOPMENTS OF RESTRAINTS, DISPLAYS, AND CONTROLS FOR USE IN SEVERE HOSTILE ENVIRONMENTS ARE NOTED. A RELATIVE HOSTILE BIOLOGICAL EFFECTIVENESS CONCEPT IS SUGGESTED FOR TEST AS A MEANS OF COMPARING THE BIOLOGICAL EFFECTS OF HOSTILE ENVIRONMENTS WITH DIFFERENT FREQUENCY COMPONENTS.

CLARK, C. C., AND CROSBIE, R.
CENTRIFUGE SIMULATION OF FLIGHT ACCELERATIONS: OPEN LOOP
COMPUTER CONTROL AND CLOSED LOOP SUBJECT-COMPUTER CONTROL OF
THE HUMAN CENTRIFUGE.
NADC LETTER REPORT TED ADC AE-1410 (NM 11 02 12.6),
'U.S. NAVAL AIR DEVELOPMENT CENTER', JOHNSVILLE, PA,
SFET 17, 1957.

* ABSTRACT *

THIS REPORT EXPLAINS A NEW TECHNIQUE OF FLIGHT SIMULATION UNDER ACCELERATION WHICH HAS BEEN DEVELOPED AT AMAL BY UTILIZING THE HUMAN CENTRIFUGE IN HOOK-UP WITH THE LARGE TYPHON ANALOG COMPUTER AT THE AERONAUTICAL COMPUTER LABORATORY. WITH THIS INCREASED CAPABILITY, THE SUBJECT UNDERGOING ACCELERATION CAN SERVE NOT ONLY AS A PASSENGER DURING A SIMULATED FLIGHT, BUT AS THE PILOT OF A SIMULATED FLIGHT THROUGH A SPECIFIED FLIGHT MANEUVER. THE PILOT-AIRCRAFT INTERACTIONS CAN BE EVALUATED UNDER G FOR THE FIRST TIME ON A CENTRIFUGE, THUS PROVIDING A MORE REALISTIC ASSESSMENT OF THE PILOT PERFORMANCE AND PHYSIOLOGICAL CHANGES DURING FLIGHT. THE CLOSED-LOOP SYSTEM WORKS IN THIS MANNER: THE CONTROL STICK, RUDDER PEDAL, AND THROTTLE SETTINGS MADE BY THE SUBJECT IN THE GONCHOLA OF THE CENTRIFUGE ARE TRANSMITTED AS ELECTRICAL SIGNALS OVER TELEPHONE LINES CONNECTING THE CENTRIFUGE WITH THE COMPUTER. THE CENTRIFUGE CONTROL SIGNALS ARE RETURNED TO AMAL THROUGH THE SPECIAL TELEPHONE LINES TO DRIVE THE CENTRIFUGE AND GIMBALS AND PROVIDE THE ACCELERATIONS THAT WOULD HAVE BEEN PROVIDED BY SIMILAR CONTROL SETTING CHANGES IN THE PARTICULAR AIRCRAFT REPRESENTED BY THE ANALOG CIRCUIT.

CLARK C.C. AND WOODLING, C.H. STUDIES OF PILOT CONTROL DURING LAUNCHING AND REENTRY OF SPACE VEHICLES UTILIZING THE HUMAN CENTRIFUGE. 'INSTITUTE OF AERONAUTICAL SCIENCES REPORT' 59-39. PRESENTED AT THE LAS 27TH ANNUAL MEETING, NEWYORK, N.Y., JAN 26-29, 1959.

* ABSTRACT *

THE PURPOSE OF THIS PAPER IS TO DESCRIBE THE HUMAN CENTRIFUGE AT THE NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA, AND TO

DISCUSS ITS USE IN PILOT-CONTROLLED FLIGHT SIMULATION AND OTHER WORK PERTINENT TO SPACE STUDIES.

CLARK, C.C. AND WOODLING C.H. CENTRIFUGE SIMULATION OF THE X-15 RESEARCH AIRCRAFT. U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PENNSYLVANIA, REPORT NO. 9, 10 DECEMBER 1959, 33 PP. AD 233 340

* ABSTRACT *

THESE X-15 CENTRIFUGE PROGRAMS HAVE DEMONSTRATED THE POTENTIALITIES OF THE CENTRIFUGE SIMULATOR, PARTICULARLY UNDER CONDITIONS OF CLOSED LOOP PILOT-COMPUTER CONTROL OR CENTRIFUGE DYNAMIC CONTROL FLIGHT SIMULATION, FOR THE STUDY OF PILOT TOLERANCE, RESTRAINT, INSTRUMENTS, CONTROLS, VEHICLE CONTROLLABILITY, CONTROL TECHNIQUES, AND TRAINING. ALTHOUGH THE CENTRIFUGE HAS ONLY THREE DEGREES OF FREEDOM OF CONTROL AND HENCE CAN ONLY PARTIALLY SIMULATE THE THREE LINEAR AND THREE ANGULAR ACCELERATIONS ON UNCONSTRAINED FLIGHT, IT HAS BEEN POSSIBLE TO SIMULATE THE PRINCIPAL FORCES OPERATING ON A PILOT AND HENCE TO 'FLY AN AIRCRAFT BEFORE IT IS BUILT'. THIS NEW TECHNIQUE OF CENTRIFUGE FLIGHT SIMULATION UNDER PILOT CONTROL SHOULD NOW JOIN THE PREVIOUS TECHNIQUES OF MATHEMATICAL DESIGN, WIND TUNNEL TESTING, STATIC CONTROL SIMULATION, AND FLIGHT IN OTHER AIRCRAFT IN CONTRIBUTING TO THE DEVELOPMENT OF THE DESIGN OF ALL NEW AND PARTICULARLY HIGH PERFORMANCE AIRCRAFT AND SPACE VEHICLES. THIS TECHNIQUE REQUIRES A LARGE COMPUTER, BUT IT IS NOTED THAT THE CENTRIFUGE HAS ALREADY BEEN OPERATED IN A PRELIMINARY WAY THROUGH TELEPHONE LINE LINKAGE TO A COMPUTER IN LANGLEY, VIRGINIA, 250 MILES AWAY. IT IS VISUALIZED THAT CENTRIFUGE DYNAMIC CONTROL SIMULATION WOULD FOLLOW THE AIRPLANE MANUFACTURER'S DEVELOPMENTAL WORK UTILIZING STATIC SIMULATION TO CONFIRM THE ADEQUACY OF THE DESIGN. BY THE USE OF TELEPHONE LINES OR MICROWAVE LINKAGE, THE MANUFACTURER'S COMPUTER, ALREADY UTILIZED FOR THE STATIC SIMULATION WORK, MIGHT BE UTILIZED IN THE CENTRIFUGE CONTROL LOOP.

CLARKE, N.F., TAUB, H., SCHERER, H.F., TEMPLE, W.E., VYKUKAL, F.E. AND MATTER, M. PRELIMINARY STUDY OF DIAL READING PERFORMANCE DURING SUSTAINED ACCELERATION AND VIBRATION. AEROSPACE MEDICAL RESEARCH LABORATORIES REPORT AMRL-TR-110, WRIGHT-PATTERSON AFB, OH, AUG. 1965.

* ABSTRACT *

BOOSTER INDUCED SPACECRAFT VIBRATIONS OCCUR IN COMBINATION WITH BOOSTER INDUCED SUSTAINED ACCELERATION. THIS WAS A JOINT NASA-AF STUDY TO PROVIDE A PRELIMINARY CURSORY EVALUATION OF THE EFFECTS OF THIS ENVIRONMENT ON CREWMEN. SIX SUBJECTS WERE USED IN 60 TESTS TO MEASURE THE DECREMENT IN DIAL READING ABILITY AS

A FUNCTION OF THE LEVEL OF 11 CPS GX VIBRATION AND THE SIZE OF THE DIAL, WHERE A BIAS ACCELERATION OF 3.85 GX WAS SUPERIMPOSED ON THE VIBRATION. DIAL READING ERRORS WERE INVERSELY RELATED TO THE ARC LENGTH OF THE INTERVAL BETWEEN DIALS AND DIRECTLY RELATED TO THE AMPLITUDE OF VIBRATION. THERE WAS APPROXIMATELY 50% DISTORTION OF THE 11 CPS VIBRATION ACCELERATION, WHICH MARKEDLY INFLUENCES THE INTERPRETATION OF RESULTS AND THEIR COMPARISON TO MEASUREMENTS OF VISUAL DECREMENTS FROM 11 CPS VIBRATIONS WITH 1GX BIAS LOADS. IN MOST GENERAL TERMS, HOWEVER, THE 3.85GX BIAS, AND/OR THE UNIDIRECTIONAL FORCE (I.E., THE RESULTANT ACCELERATION WAS ALWAYS GREATER THAN 0 G) CREATES A SUBJECTIVELY MORE TOLERABLE ENVIRONMENT THAN WITH A 1 G BIAS. VIBRATIONS OF 3.85 GX + OR - 3.0 GX WERE WITHOUT SERIOUS SUBJECTIVE EFFECTS IN EXPOSURES OF 90 SECONDS DURATION. GROSS COMPARISONS OF DIAL READING PERFORMANCE UNDER THE TWO CONDITIONS PROVIDE SOME INDICATION THAT THE GREATER BIAS ACCELERATION IS ASSOCIATED WITH LESS VISUAL DECUREMENT.

CLARKE, N. P., WOLFF, W. M., GOKELMAN, J. J., VON GIERKE, H. E.
SIMULATION OF AEROSPACE FLIGHT ACCELERATION AND DYNAMIC
PRESSURE ENVIRONMENTS FOR BIODYNAMICS RESEARCH.
'AIAA/AFLC/ASD SUPPORT FOR MANNED FLIGHT CONFERENCE',
AIAA PAPER 65-279, DAYTON, OH, APRIL 21-23, 1965.

* ABSTRACT *

THE OPERATIONAL ACCELERATION ENVIRONMENTS GENERATED BY FLIGHT IN AEROSPACE VEHICLES RANGE FROM PROLONGED PERIODS OF WEIGHTLESSNESS TO EXTREMELY BRIEF HIGH MAGNITUDE IMPACT FORCES RESULTING FROM GROUND LANDING. COMPLEX LINEAR AND ANGULAR VIBRATIONS ARE PRODUCED EITHER SINGLY OR IN COMBINATION AND MAY BE SUPERIMPOSED ON SUSTAINED ACCELERATIONS SUCH AS THOSE PRODUCED BY BOOSTER ROCKETS. INFRASONIC NOISE OF HIGH LEVEL AND AIRBORNE BOOSTER INDUCED VIBRATIONS ARE ALSO PART OF THE ENVIRONMENTAL PROBLEMS PRODUCED BY LARGE VEHICLES. IN THE PAST, LABORATORY SIMULATORS HAVE, BECAUSE OF TECHNICAL LIMITATIONS, USUALLY BEEN RESTRICTED TO REPRODUCE ISOLATED SEGMENTS OF THE OPERATIONAL ENVIRONMENT. THE NEXT GENERATION OF SIMULATORS WILL PROVIDE THE ABILITY TO CREATE THE HIGH MAGNITUDE COMPLEX ACCELERATIONS OF OPERATIONAL ENVIRONMENTS FOR EXPLORATION OF THE BIOMECHANICS, PHYSIOLOGIC AND PERFORMANCE CHANGES RESULTING FROM EXPOSURE OF HUMANS AND ANIMALS TO THESE ENVIRONMENTS. IN THIS LABORATORY, THE SIX-MODE (SIX DEGREE OF FREEDOM MOTION DEVICE), THE DYNAMIC PRESSURE CHAMBER (AN INFRASONIC NOISE CHAMBER), AND THE DYNAMIC ESCAPE SIMULATOR, (A SOPHISTICATED CENTRIFUGE), ARE UNDER CONSTRUCTION. THE SPECIFIC DESIGN CHARACTERISTICS AND PERFORMANCE RANGE OF THESE DEVICES WILL BE COMPARED TO THE ENVIRONMENTS PRODUCED BY OPERATIONAL CONDITIONS AND TO EXISTING LABORATORY SIMULATION FACILITIES. (AUTHORS)

CLAUSING, L.A. 'SIMULATOR REQUIREMENTS DEDUCED FROM COMPARISONS OF PILOTS PERFORMANCE IN GROUND SIMULATORS AND IN AIRCRAFT'. PAPER NO. 64-554 INTERNATIONAL COUNCIL OF THE AERONAUTICAL SCIENCES, PARIS FRANCE AUGUST 24-28, 1964.

* ABSTRACT *

LITERATURE REVIEW. THE IMPORTANT FACTORS IN GROUND SIMULATION ARE:

1. VISUAL CUES AND TASK CRITERIA IN JET TRANSPORT LANDINGS,
2. MOTION CUES, VISUAL CUES, COCKPIT SOPHISTICATION, AND EXACT GROUND EFFECT PARAMETERS IN TAKE-OFF CERTIFICATION STUDIES, AND
3. SOPHISTICATED MOTION SIMULATION AND CONTROL CHARACTERISTICS DUPLICATION IN STOL LANDING APPROACH STUDIES.

COHEN, E. 'IS MOTION NEEDED IN FLIGHT SIMULATORS FOR TRAINING', HUMAN FACTORS, 1970, 12, 75-79.

* ABSTRACT *

ALTHOUGH FLIGHT TRAINING CURRICULAR DEMAND THAT PILOTS LEARN TO DISREGARD BODILY SENSATIONS OF MOTION, AIRCRAFT MOTION CAN BE AN IMPORTANT SOURCE OF INFORMATION TO PILOTS, AND SOMETIMES A DEGRADER OF PILOT PERFORMANCE. CONSIDERABLE EVIDENCE IS ADDUCED THAT MOTION IN FLIGHT SIMULATORS PRODUCES SIGNIFICANT TRAINING BENEFITS, BUT THERE IS A SCARCITY OF DATA ON THE CONSEQUENCES OF DIFFERENT DEGREES OR METHODS OF MOTION SIMULATION. TO PRODUCE THE SENSATION OF MILES OF AIRCRAFT MOTION WITH A FEW FEET OF SIMULATOR MOTION, REQUIRES CONSIDERATION OF VARIOUS ASPECTS OF HUMAN SENSITIVITY TO MOTION. SOME OF THE COMPLICATIONS IN OBTAINING MOTION THRESHOLD DATA ARE DISCUSSED, AND TWO ILLUSTRATIONS OF THE UTILIZATION OF THESE DATA IN OPTIMIZING MOTION SIMULATION ARE GIVEN.

COHEN, E. 'HOW MUCH MOTION IS REALLY NEEDED IN FLIGHT SIMULATORS', LINK DIVISION, THE SINGER CO. PAPER PRESENTED AT THE FOURTH INTERNATIONAL SIMULATION AND TRAINING CONFERENCE, SAE, ATLANTA, GA. MAY 13, 1971.

* ABSTRACT *

ALTHOUGH THE NEED FOR MOTION ON FLIGHT SIMULATORS USED FOR TRAINING IS WELL ACCEPTED, THERE IS A WIDE DIVERGENCE OF OPINION ON THE KIND AND AMOUNT OF MOTION REQUIRED. THIS PAPER REVIEWS THE REQUIREMENTS FOR MOTION IN EACH OF THE SIX DEGREES OF FREEDOM AND SUGGESTS THE EXTENT OF MOTION DESIRABLE IN EACH, AS WELL AS WAYS TO EXPLOIT GIVEN MOTION SYSTEM GEOMETRY.

THE AUTHOR CONCLUDES THAT MOTION IN AT LEAST FIVE (ALL BUT YAW OR LATERAL) OF THE SIX DEGREES OF FREEDOM IS REQUIRED TO PROVIDE FEEDBACK FULLY TO THE PILOT ON HIS CONTROL ACTIONS. PITCH AND ROLL CAPABILITY SIMILAR TO THAT OF A TRANSPORT AIRCRAFT IS DESIRABLE; DISPLACEMENTS IN THE THREE LINEAR DEGREES OF FREEDOM NEED TO BE ON THE ORDER OF \pm OR \approx 2.04 FT. IN ORDER TO PROVIDE A CAPABILITY FOR TWO SUCCESSIVE ONSET CUES.

COHEN, E., AND SIMON, G.B. 'THE SIMULATION OF MOTION FOR TRAINING AND FOR RESEARCH'. ARMED FORCES - NRC COMMITTEE ON BIOASTRONAUTICS, 6-11, 1961, NASA

* ABSTRACT *

WE ARE CONCERNED WITH FIVE DIFFERENT KINDS OF MOTION OR ACCELERATION: MULTIGRAVITY, SUBGRAVITY, TUMBLING, BUFFETING, AND VIBRATION, AND TRANSIENTS ARE RELEVANT IN THE SIMULATION OF CONVENTIONAL AIRCRAFT. IN A FAIRLY RECENT REVIEW, MUCKLER, NYGAARD, O'KELLY AND WILLIAMS CONCLUDE THAT IT IS APPARENT THAT THE CURRENT TREND IN DESIGN IS TOWARD FIXED SIMULATORS.

THE PRESENCE OF MOTION IN A SIMULATOR CAN SERVE AS SIGNAL OR NOISE. THE SIGNAL ENABLES THE PILOT TO FLY BY THE SEAT OF HIS PANTS. THE NOISE RELATES TO THE EFFECT THAT MOTION HAS ON THE READING OF DISPLAYS, THE MANIPULATION OF CONTROLS AND OTHER ASPECTS OF THE PILOTS JOB.

THEY TALK MORE ABOUT SIMULATION OF MOTION FOR RESEARCH RATHER THAN FOR TRAINING. THE REASON IS THAT SIMULATION FOR TRAINING IS RATHER UNIVERSALLY ACCEPTED WHILE SIMULATION FOR RESEARCH IS NOT, EVEN THOUGH THERE IS A TREMENDOUS AMOUNT OF RESEARCH REQUIRED TO MAKE MAN USEFUL IN SPACE AND MUCH OF THIS RESEARCH CAN BEST BE CONDUCTED ON SIMULATORS.

COHEN, M.M., CROSBIE, RICH AND BLACKBURN, L.H. DISORIENTATING EFFECTS OF AIRCRAFT CATAPULT LAUNCHINGS. 'AEROSPACE MEDICINE', VOL. 44, '1', JAN. 1973, 37-39.

* ABSTRACT *

THE NAVAL AIR DEVELOPMENT CENTER'S HUMAN CENTRIFUGE WAS USED TO GENERATE ACCELERATION PROFILES APPROXIMATING THOSE ENCOUNTERED IN AIRCRAFT CATAPULT LAUNCHINGS. TWELVE SUBJECTS ATTEMPTED TO KEEP A CONTINUOUSLY MOVING TARGET AT SUBJECTIVE EYE LEVEL BEFORE, DURING, AND AFTER EXPOSURE TO THE ACCELERATIONS. OUR RESULTS SHOWED THAT SUBJECT EYE LEVEL WAS CHANGED BY EXPOSURE TO THE ACCELERATIONS, AND THAT, IN SOME INDIVIDUALS, THE CHANGE PERSISTED FOR MORE THAN 1 MINUTE AFTER THE SIMULATED LAUNCH SEQUENCE WAS COMPLETED. THE RESULTS ARE DISCUSSED IN TERMS OF

EFFECTS OF ROTATED ACCELERATION VECTORS ON HUMAN SPATIAL ORIENTATION, AND THE DATA ARE RELATED TO CERTAIN TYPES OF AIRCRAFT LOSSES THAT HAVE BEEN REPORTED FOLLOWING CATAPULT LAUNCHINGS AT NIGHT.

COLLACOTT, R. (EDITOR) 'SIMULATORS INTERNATIONAL GUIDE', GOWER REFERENCE PUBLICATIONS: REDWOOD PRESS LTD., TROWBRIDGE, WILTSHIRE, ENGLAND. 1973.

* ABSTRACT *

PRODUCING THIS BOOK HAS OCCUPIED SEVERAL YEARS RESEARCH WITH TRANSLATION FROM AND INTO A NUMBER OF DIFFERENT LANGUAGES. THE ORIGINAL CONCEPT AROSE FROM A TRAINING FEASIBILITY STUDY AND THE NEED FOR TRAINING SIMULATORS, INVOLVING A STUDY OF THIS ASPECT OF THE SUBJECT AND THE EVALUATION OF DIFFERENT FORMS OF SIMULATOR. AFTER AN ACADEMIC SUBMISSION HAD BEEN PREPARED IT WAS RECOMMENDED THAT THE SCOPE OF THE STUDY SHOULD BE EXTENDED AND THIS HAS LED TO THE PRESENT FORM OF THIS BOOK.

INFORMATION WAS RECEIVED FROM CORRESPONDENTS IN VARIOUS COUNTRIES OCCASIONALLY IN A FORM SUGGESTED IN A QUESTIONNAIRE, MORE OFTEN BY WAY OF VOLUMINOUS REPORTS WITH AN INVITATION TO USE RELEVANT MATERIAL TO PREPARE ENTRIES FOR THIS BOOK. THE PLAN WHICH HAS BEEN FOLLOWED IN MAKING THESE ENTRIES HAS BEEN TO SUPPLY, FOR EACH NUMBERED ENTRY:

NAME OR TITLE: (THAT BY WHICH THE SIMULATOR IS COMMONLY KNOWN BY ITS ORIGINATORS)

OBJECTIVE: (WHAT IS HOPED TO ACHIEVE FROM THE SIMULATOR)

FEATURES: (A DESCRIPTION OF THE SIMULATOR - TO SOME EXTENT A DESCRIPTIVE SPECIFICATION)

FACILITIES: (WHAT THE SIMULATOR HAS BEEN USED TO DO)

CAPABILITIES: (OTHER FACILITIES OF WHICH THE SIMULATOR IS CAPABLE BUT WHICH HAVE NOT NECESSARILY BEEN ATTEMPTED)

LOCATION: (WHERE THE SIMULATOR IS SITUATED)

FURTHER INFORMATION: (THE NAME, ADDRESS, TELEPHONE NUMBER, TELEX ADDRESS OF THE ORGANIZATION POSSESSING THE SIMULATOR AND THE NAME(S) OF THE PERSON(S) DIRECTLY CONCERNED WITH IT).

EACH ENTRY HAS BEEN ALLOCATED TO ONE OF THE FOLLOWING THREE CATEGORIES:

- (1) RESEARCH & DEVELOPMENT
- (2) TRAINING (INCLUDING EDUCATION AND TEACHING)
- (3) TESTING

CONNELLY, M. E. SIMULATION OF AIRCRAFT.
SERVOMECHANISMS LABORATORY OF THE DEPARTMENT OF ELECTRICAL ENGINEERING, MIT, 7591-R-1, FEBRUARY 1958.

* ABSTRACT *

THIS REPORT IS AN OUTGROWTH OF A ONE-YEAR STUDY OF THE EQUATIONS OF MOTION AND THE COMPUTING TECHNIQUES USED IN THE AERODYNAMIC COMPUTER SECTION OF OPERATIONAL FLIGHT TRAINERS. ONE OF THE OBJECTIVES OF THE STUDY WAS TO STANDARDIZE AND SIMPLIFY, INsofar AS POSSIBLE, THE MATHEMATICAL MODEL USED TO REPRESENT AN AIRCRAFT IN FLIGHT. IN THIS CONNECTION, AN EXTENSIVE ANALYSIS OF AXIS SYSTEMS, BASIC DYNAMICS, AND AERO-DYNAMIC COEFFICIENTS WAS CARRIED OUT. DIGITAL AND ANALOG SIMULATION STUDIES WERE EMPLOYED TO DETERMINE ALLOWABLE SIMPLIFICATIONS IN THE EQUATIONS OF MOTION. THE RESULTS OF THIS WORK ARE SUMMARIZED IN THE FOLLOWING REPORT.

ALTHOUGH THE EMPHASIS IS ON FLIGHT SIMULATORS USED FOR TRAINING PURPOSES, THE MATERIAL PRESENTED IS GENERALLY APPLICABLE TO THE ENTIRE FIELD OF FLIGHT SIMULATION.

CHNRAD, B.
OPERATIONAL DEVELOPMENT OF MOTION WASHOUT TECHNIQUES.
ANALYTICAL MECHANICS ASSOCIATES, MOUNTAIN VIEW, CA.
FOR AMES RESEARCH CENTER, MOFFETT FIELD, CA.
REPORT NO. NASA CR-137519

* ABSTRACT *

DURING THE THREE YEAR PERIOD FROM 1968-1971, ANALYTICAL MECHANICS ASSOCIATES, INC., WITH THE SUPPORT AND ASSISTANCE OF NASA AMES RESEARCH CENTER, DEVELOPED AND DOCUMENTED PROCEDURES FOR DESIGNING MULTI-DEGREE OF FREEDOM WASHOUT LOGIC FOR SIMULATORS SUCH AS THE A11-AXES AND FSAA SIMULATION SYSTEMS. THIS REPORT SUMMARIZES THE WORK PERFORMED UNDER AN EFFORT DIRECTED TOWARD THE SMOOTH IMPLEMENTATION OF THE PREVIOUSLY DEVELOPED IDEAS INTO OPERATIONAL USE ON AMES SIMULATORS. THE THRUST OF THIS EFFORT FELL INTO THREE AREAS INCLUDING:

1. THE IMPLEMENTATION OF GENERAL PURPOSE WASHOUT LOGIC THAT CAN SIMULATE THE RESPONSES OF SEVERAL PREVIOUSLY DEVELOPED TYPES WITHOUT USING SEVERAL DIFFERENT SOFTWARE PACKAGES, DEVELOPED FOR EXPERIMENTAL PURPOSES.
2. SOLUTION OF SPECIFIC PROBLEMS THAT MIGHT ARISE FROM TIME TO TIME IN THE OPERATION AND MODIFICATION OF OPERATIONAL WASHOUT LOGIC, AND
3. THE PRODUCTION OF A WASHOUT MANUAL DESCRIBING THE DIGITAL WASHOUT IN USE ON THE SIMULATORS.

IN ADDITION, A JOINT NASA/AMA PAPER WAS PRESENTED AT THE AIAA VISUAL AND MOTION SIMULATION CONFERENCE.

SECTION II DISCUSSES THE GENERAL PURPOSE WASHOUT CIRCUIT. SECTION III PRESENTS ANALYSIS RELATED TO OPERATIONAL PROBLEMS

THAT HAVE BEEN INVESTIGATED BY AMA. SECTION IV IS A BRIEF DISCUSSION OF THE WASHOUT MANUAL. THE MANUAL ITSELF HAS BEEN SEPARATELY BOUND AND IS A SELF-STANDING DOCUMENT WHICH IS SUITABLE FOR DISTRIBUTION TO USERS OF THE AMES SYSTEM.

* APPENDIX *

ANALYTICAL MECHANICS ASSOCIATES MOUNTAIN VIEW, CA.
SIMULATOR WASHOUT MANUAL. FOR THE AMES ALL AXIS AND FSAA MOTION SYSTEMS. REPORT NO. 73-53, DECEMBER 1973.

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THIS MANUAL IS DESIGNED TO ACQUAINT USERS OF THE AMES FSAA AND ALL-AXIS SIMULATORS WITH SOME OF THE THEORY AND MECHANICS OF THE MOTION DRIVE SYSTEMS. BOTH COCKPITS ARE MOUNTED IN THREE GIMBALLS WHICH ARE, IN TURN, MOUNTED ON A PLATFORM CAPABLE OF TRANSLATING IN THREE ORTHOGONAL DIRECTIONS.

THE DOCUMENT IS CONCERNED WITH:

1. THE MOTION DRIVE TRAINS (CAPABILITIES AND LIMITATIONS)
2. PILOT SENSED MOTION CUES
3. THE MOTION WASHOUT LOGIC WHICH COMMANDS CAB MOTION BASED ON A COMPROMISE BETWEEN SIMULATED AIRCRAFT MOTION AND CAB CAPABILITIES.

SECTION II PRESENTS A QUALITATIVE DESCRIPTION OF THE RELATIONSHIP BETWEEN THESE AREAS AND OTHER ASPECTS OF A FULL-PLANE SIMULATION.

SECTION III PROVIDES QUANTITATIVE INFORMATION ON THE HARDWARE USED TO MOVE THE SIMULATOR CABS.

SECTION IV DISCUSSES MOTION IN TERMS OF THOSE CUES WHICH A PILOT CAN POTENTIALLY SENSE AND THOSE WHICH A SIMULATOR CAB MIGHT PROVIDE.

SECTION V DELINEATES THE PRINCIPLES BEHIND THE DIGITAL COMPUTATIONS THAT CONSTITUTE THE WASHOUT LOGIC.

CONRAD, P., DOUVILLIER, J.G. AND SCHMIDT, S.F. WASHOUT CIRCUIT DESIGN FOR MULTI-DEGREES-OF-FREEDOM MOVING BASE SIMULATORS. AIAA VISUAL AND MOTION SIMULATION CONFERENCE, PALO, ALTO, CALIF. CALIFORNIA/SEPTEMBER 10-12, 1973, AIAA PAPER NO. 73-929.

* ABSTRACT *

PILATED, MOVING-BASE SIMULATORS GENERALLY CONTAIN ACTUATORS AND DRIVE LINKAGES WITH SEVERE POSITION, VELOCITY, AND/OR ACCELERATION LIMITS. THESE LIMITS PREVENT THE MOTION DRIVE TRAINS FROM EXACTLY REPRODUCING THE VERY GENERAL MOTION HISTORIES THAT MAY BE SOLVED FOR AN IN-AIRCRAFT COMPUTER SIMULATION. THIS PAPER PRESENTS A MATHEMATICAL FRAMEWORK FOR DESIGNING LOGIC TO ACCEPT MOTION-DEPENDENT PARAMETERS FROM A SIMULATION, ATTENUATING THEM (WASHING THEM OUT) AND GENERATING APPROPRIATELY LIMITED DRIVE SIGNALS. THIS FRAMEWORK IS SUFFICIENTLY GENERAL TO ENCOMPASS SIX-DEGREES-OF-FREEDOM SIMULATORS WITH LARGE MOTION CAPABILITY. EMPHASIS IS PLACED ON PRESERVING CERTAIN MOTION CUE RELATIONS (SUCH AS THOSE THAT WOULD BE OBSERVED IN COORDINATED FLIGHT). STRATEGIES FOR

SIMULATING SIDE FORCES VIA TILTS ARE SHOWN. FINALLY, SEVERAL SPECIFIC CIRCUITS ARE SHOWN. THESE CIRCUITS HAVE PROVEN TO BE READILY ADAPTABLE TO A VARIETY OF MOVING-BASE SIMULATORS.

CONRAD, B. AND SCHMIDT, S.F. 'A STUDY OF TECHNIQUES FOR CALCULATING MOTION DRIVE SIGNALS FOR FLIGHT SIMULATORS'. CR-114345, JULY 1971, NASA.

* ABSTRACT *

OBJECTIVES

1. DEVELOP AN EXPERIMENTAL TEST PLAN USING THE FORMATION-FLYING TASK FOR THE VALIDATION AND REFINEMENT OF THE WASHOUT CIRCUITS DESCRIBED IN REFERENCE 1. THE DETAILS OF THIS PLAN ARE GIVEN IN SECTION 2.
2. EXECUTE THE TEST PLAN IN CONJUNCTION WITH NASA SCIENTISTS AND TEST PILOTS ON THE AMES SIMULATION FACILITIES. SOME OF THE EXPERIMENTAL RESULTS OBTAINED IN THESE TESTS ARE GIVEN IN SECTION 3.
3. ANALYZE THE EXPERIMENTAL DATA IN CONJUNCTION WITH NASA SCIENTISTS, USING PILOT MODEL IDENTIFICATION METHODS. DIFFICULTIES ENCOUNTERED WITH THESE PROCEDURES ARE GIVEN IN SECTION 4, ALONG WITH A FEW PRELIMINARY RESULTS.
4. DEVELOP FORTRAN IV WASHOUT PROGRAMS FOR APPLICATIONS ON THE AMES ALL-AXIS SIMULATOR. TWO SUCH PROGRAMS ARE DESCRIBED IN THE APPENDIX. SECTION 5 DESCRIBES THE USE OF THESE CIRCUITS.
5. DEVELOP A QUESTIONNAIRE-TYPE LOG TO ASSIST NASA PERSONNEL IN DOCUMENTING THE EXPERIENCE OBTAINED WITH THE APPLICATION OF WASHOUT CIRCUITS TO OPERATIONAL SIMULATIONS. THIS LOG IS PRESENTED IN SECTION 6.

SECTION 7 REVIEWS THE OVERALL STUDY EFFORT AND GIVES RECOMMENDATIONS FOR FUTURE INVESTIGATIONS.

COOPER, G.E. UNDERSTANDING AND INTERPRETING PILOT OPINION, 'AERONAUTICAL ENGINEERING REVIEW', MARCH 1957, PP. 47-50.

* ABSTRACT *

IT IS FELT THAT PERHAPS THE MOST IMPORTANT FACTOR IN OBTAINING RELIABLE PILOT OPINION LIES IN THE FORMULATION OF THE PROPER QUESTION OR TASK TO BE ASKED THE PILOT. IN ANSWERING THIS QUESTION, WHICH IDEALLY THE TEST PILOT HAS HELPED TO FORMULATE, HE MUST EXPRESS HIS OPINION AT SOME TIME OR OTHER IN TERMS OF AN ADJECTIVE RATING SYSTEM. AS A STEP TOWARD A MORE UNIVERSAL

CALIBRATION OF PILOT OPINION, SOME STANDARDIZATION OF RATING SYSTEMS WOULD BE DESIRABLE.

THE EXPRESSION AND INTERPRETATION OF PILOT OPINION MUST CONSIDER ALSO SUCH FACTORS AS THE PILOT'S PRESENT VIEWPOINT, BACKGROUND, EXPERIENCE, AND ADAPTABILITY.

IT IS ALSO CONCLUDED THAT GROUND SIMULATORS IN CONJUNCTION WITH A HUMAN PILOT ARE VALUABLE TOOLS FOR EVALUATING A PARTICULAR AIRPLANE OR CONTROL SYSTEM CHARACTERISTIC, BUT, BECAUSE OF THE VERY REAL DANGER OF MAKING INVALIDATING ASSUMPTIONS, IT IS IMPORTANT THAT THE TEST PILOT SHARE THE RESPONSIBILITY FOR THEIR DESIGN AND USE.

COMMENT ON PILOT WORKLOAD: UNTIL THE PSYCHOLOGISTS COME ALONG WITH SOME SORT OF DEVICE FOR MEASURING PILOT WORK OR CONCENTRATION, THE CHIEF RELIANCE WILL CONTINUE TO BE PLACED ON PILOT OPINION OF THE VARIOUS DEGREES OF ACCEPTABILITY OF PILOT EFFORT INVOLVED IN PERFORMING A GIVEN TASK...

COMMENTS ON MOTION: USING THE GROUND SIMULATOR TO DETERMINE THE MINIMUM COMFORTABLE LANDING SPEED, PILOTS FOUND THAT THE EFFECTS OF MOTION CAN BE IGNORED. A PILOTING TASK ON WHICH MOTION STIMULI WERE FOUND TO BE OF PRIMARY IMPORTANCE IS THE PITCH-UP. IT WAS DETERMINED BY PILOT OPINION, THAT PITCHING ACCELERATION WAS THE PRIMARY MOTION STIMULUS TO WHICH HE WAS SENSITIVE. ANOTHER TASK FOR DETERMINATION OF WHETHER OR NOT MOTION IS REQUIRED IS A TRACKING TASK USING A SCOPE PRESENTATION. COMPARISON OF GROUND SIMULATION AND FLIGHT TESTS INDICATE THAT PILOT CONTROL IS QUITE DIFFERENT WHEN THEIR ONLY STIMULUS IS VISUAL, AS ON THE GROUND, FROM THEIR REACTIONS WHEN THEY ALSO HAVE MOTION STIMULI IN THE AIR. THIS STUDY IS CONTINUING IN AN EFFORT TO DETERMINE THE IMPORTANT MOTION CUE.

COOPER, G.E. THE USE OF PILOTED FLIGHT SIMULATORS IN TAKE-OFF AND LANDING RESEARCH. NORTH ATLANTIC TREATY ORGANIZATION, AGARD-R-430, 1963

* ABSTRACT *
A NASA TEST PILOT GIVES HIS CONCLUSIONS FROM A NUMBER OF YEARS AIRCRAFT AND SIMULATOR RESEARCH. PITCH, ROLL, AND SUSTAINED HEAVE FORCES THOUGHT TO BE ESPECIALLY IMPORTANT, SINCE THEY FORM EITHER USEFUL INFORMATION OR A REALISTIC DISTRACTION. SWAY ACCELERATIONS THOUGHT TO BE NECESSARY TO REPRESENT ENGINE FAILURE CONDITIONS. TWO EXPERIMENTS QUOTED IN WHICH VFA VISUAL CUES THOUGHT TO HAVE COMPENSATED FOR ABSENT MOTION CUES.

COOPER, G.E. SIMULATOR STUDY OF MOTION REQUIREMENTS FOR SIMULATING ENGINE FAILURES. MEMO FOR DIRECTOR, NASA AMES, MAY, 1966.

* ABSTRACT *

ONSET AND VERY BRIEF SUSTAINED G LEAD TO ADEQUATE REPRESENTATION FOR SIMULATING ENGINE FAILURE, EVEN FOR EXCURSIONS PROGRAMMED TO BE AS LOW AS 4 INCHES. CONDITION IS THAT DISTURBING WASHOUT MOTIONS CAN BE MINIMIZED.

COOPER, G.E. AND HARPER, R.P. JR.
THE USE OF PILOT RATING IN EVALUATION OF AIRCRAFT HANDLING QUALITIES. 'NASA TECHNICAL NOTE TN-D-5153' APRIL, 1969.
ALSO AGARD REPORT 567, APRIL 1969.

* ABSTRACT *

PILOT RATING SCALES AND THEIR USE IN ASSESSING AIRCRAFT HANDLING QUALITIES ARE REVIEWED HISTORICALLY, AND OBJECTIONS THAT HAVE BEEN RAISED TO LIMITATIONS OF EARLIER SCALES ARE CONSIDERED IN THE DEVELOPMENT OF A REVISED SCALE. TERMINOLOGY USED IN THE EVALUATION OF HANDLING QUALITIES IS REVIEWED AND NEW DEFINITIONS ARE PROPOSED TO IMPROVE COMMUNICATION AND INTERNATIONAL UNDERSTANDING. OF PARTICULAR SIGNIFICANCE IS THE NEW DEFINITION OF HANDLING QUALITIES, WHICH EMPHASIZES THE IMPORTANCE OF FACTORS THAT INFLUENCE THE SELECTION OF A RATING OTHER THAN STABILITY AND CONTROL CHARACTERISTICS.

THE EXPERIMENTAL USE OF PILOT RATING IS DISCUSSED IN DETAIL, WITH SPECIAL ATTENTION DEVOTED TO (1) CLARIFYING THE DIFFERENCE BETWEEN MISSION AND TASK, (2) IDENTIFYING WHAT THE RATING APPLIES TO, (3) CONSIDERING THE PILOT'S ASSESSMENT CRITERIA, AND (4) DEFINING THE SIMULATION SITUATION. THE IMPORTANT ELEMENTS OF THE REPORT ARE THEN SUMMARIZED IN A SUGGESTED 'BRIEFING GUIDE', DESIGNED FOR GUIDANCE IN PLANNING AND EXECUTING HANDLING QUALITIES EXPERIMENTS.

COPELAND, V.L., KAHLBAUM, W.M. JR, BARKER, L.E.,
STEINMETZ, G.G., AND GROVE, R.D. AEROSPACE TECHNOLOGISTS, NASA
LANGLEY RESEARCH CENTER, HAMPTON, VA.
THE DESIGN OF DUAL WIDE ANGLE VISUAL CUE SIMULATORS AND THE
ANALYSIS OF MULTIAXIS PROJECTION EQUIPMENT (AIAA CONF. MARCH
16-18 1970 (CAPE)) V70-256

* ABSTRACT *

THE SIMULATOR DESIGN PROVIDES INDEPENDENT, SIMULTANEOUS VISUAL ENVIRONMENT AND PILOT FLIGHT STATIONS, ALLOWING RESEARCH TO BE CONDUCTED WITH TWO PILOTED VEHICLES IN A DIFFERENTIAL MODE, EITHER COOPERATIVE OR NONCOOPERATIVE. ATTENTION IS GIVEN TO THE ANALYSES OF DESIGN APPROACHES WHICH LED TO SELECTED HARDWARE DESIGNS WHICH MAXIMIZED THE PILOT'S FIELD OF VIEW, MINIMIZED OCCLUSIONS AND PARALLAX IN THE PILOT'S SCENE, AND MAXIMIZED THE DYNAMIC RANGE OF THE FLIGHT PARAMETERS. IN PARALLEL TO A

DETAILED DESIGN PHASE, EXTENSIVE ANALYSES AND COMPUTER SIMULATIONS HAVE BEEN CONDUCTED USING THE ACTUAL DESIGN PARAMETERS. THESE STUDIES WERE DIRECTED TOWARD: 1) THE OPTIMIZATION OF FOUR-AXIS GIMBAL LOGIC USED IN AVOIDING GIMBAL LOCK 2) EVALUATION OF THE EFFECTS OF TORQUE COUPLING BETWEEN AXES OF FOUR-GIMBAL SYSTEMS, AND 3) THE ACHIEVEMENT OF SCENE SYNCHRONIZATION THROUGH MATCHING THE DYNAMIC RESPONSES OF INDEPENDENT SERVOMECHANISMS.

CORRINGDALE, K.G. AND BENSON, A.J. 'PHYSIOLOGICAL AND PSYCHOLOGICAL FACTORS INFLUENCING VEHICLE SIMULATION'. VEHICLE SIMULATION FOR TRAINING AND RESEARCH, R.A.F. INSTITUTE OF AVIATION MEDICINE, IAM REPORT NO. 442 FARNBOROUGH, HANTS, MARCH 1968.

* ABSTRACT *

ABSTRACT (SECTIONS RELEVANT TO MOTION)
SOME OF THE CUES RELEVANT TO VEHICLE BEHAVIOR ARE OBTAINED FROM MECHANORECEPTORS. THESE RECEPTORS ARE STIMULATED BY MECHANICAL FORCES AND HENCE SIGNAL THE ACCELERATIONS OF THE VEHICLE AND ITS ORIENTATION TO THE GRAVITATIONAL ACCELERATION. ACCORDINGLY THEY PROVIDE A SIGNIFICANT INPUT TO THE CONTROLLER OF THE VEHICLE, WHICH MAY IN CERTAIN CIRCUMSTANCES, BE MORE READILY PERCEIVED THAN THE CONCOMITANT VISUAL CUES. ALTERNATIVELY, MOTION, OR MORE SPECIFICALLY ACCELERATIONS, CAN INTERFERE WITH CONTROL BY DEGRADING THE OPERATOR'S ABILITY TO PERCEIVE THOSE CUES WHICH INFORM HIM ABOUT THE BEHAVIOR OF THE VEHICLE, EITHER BY THE INTRODUCTION OF DISTRACTING AND DISTURBING SENSORY STIMULI, OR BY DISRUPTING THE FINE HAND AND FOOT MOVEMENTS BY WHICH HE EXERCISES CONTROL.

AGREES THAT MOTION SIMULATION MAY OR MAY NOT BE NECESSARY DEPENDING UPON THE PURPOSE OF THE SIMULATOR.

OUTLINES THE NON-VISUAL SENSORY MECHANISMS BY WHICH MAN PERCEIVES MOTION.

THE MECHANORECEPTORS WHICH PROVIDE THE OPERATOR WITH INFORMATION ABOUT THE MOTION OF THE VEHICLE ARE STIMULATED ONLY BY ACCELERATION AND THAT, WITH THE EXCEPTION OF THE VESTIBULAR APPARATUS, THESE RECEPTORS ADAPT QUICKLY, THUS, BY EXPOSING THE OPERATOR TO A COMPONENT OF THE COMPUTED ACCELERATION OF THE VEHICLE, IT HAS BEEN POSSIBLE TO CREATE AN ACCEPTABLE ILLUSION OF VEHICLE MOTION, IN OTHER WORDS TO PRODUCE PERCEPTUAL EQUIVALENCE. HOWEVER, THIS TECHNIQUE FAILS TO SIMULATE SUSTAINED ACCELERATIONS. CENTRIFUGES CAN BE USED FOR SUSTAINED ACCELERATIONS BUT THEY NECESSARILY PRODUCE ANGULAR ACCELERATIONS ALSO WHICH MAY LEAD TO THE DEVELOPMENT IN THE OPERATOR OF AN INCORRECT ASSOCIATION BETWEEN VEHICLE MOTION AND THE ACCOMPANYING SOMAESTHETIC SENSATIONS.

P.R. CORLYON - MOTION SYSTEM
 PATENT NO. 3,494,052
 FILED APRIL 10, 1967 GRANTED FEB. 10, 1970

NO ABSTRACT

 CREER, B.Y., SMEDAL, H.A. AND WINGROVE, R.C. 'CENTRIFUGE STUDY
 OF PILOT TOLERANCE TO ACCELERATION AND THE EFFECTS OF ACCELE-
 RATION ON PILOT PERFORMANCE'. NASA TN D-337, NOVEMBER 1960.

* ABSTRACT *

A RESEARCH PROGRAM, THE GENERAL OBJECTIVE OF WHICH WAS TO MEASURE THE EFFECTS OF VARIOUS SUSTAINED ACCELERATIONS ON THE CONTROL PERFORMANCE OF PILOTS, WAS CARRIED OUT ON THE AVIATION MEDICAL ACCELERATION LABORATORY CENTRIFUGE, U. S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA. THE EXPERIMENTAL SETUP CONSISTED OF A FLIGHT SIMULATOR WITH THE CENTRIFUGE IN THE CONTROL LOOP. THE PILOT PERFORMED HIS CONTROL TASKS WHILE BEING SUBJECTED TO ACCELERATION FIELDS SUCH AS MIGHT BE ENCOUNTERED BY A FORWARD-FACING PILOT FLYING AN ATMOSPHERE ENTRY VEHICLE. THE STUDY WAS DIVIDED INTO THREE PHASES.

IN ONE PHASE OF THE PROGRAM, THE PILOTS WERE SUBJECTED TO A VARIETY OF SUSTAINED LINEAR ACCELERATION FORCES WHILE CONTROLLING VEHICLES WITH SEVERAL DIFFERENT SETS OF LONGITUDINAL DYNAMICS. HERE, A RANDOMLY MOVING TARGET WAS DISPLAYED TO THE PILOT IN A CATHODE-RAY TUBE. FOR EACH COMBINATION OF ACCELERATION FIELD AND VEHICLE DYNAMICS, PILOT TRACKING ACCURACY WAS MEASURED AND PILOT OPINION OF THE STABILITY AND CONTROL CHARACTERISTICS WAS RECORDED. THUS, INFORMATION WAS OBTAINED ON THE COMBINED EFFECTS OF COMPLEXITY OF CONTROL TASK AND MAGNITUDE AND DIRECTION OF ACCELERATION FORCES ON PILOT PERFORMANCE. THESE TESTS SHOWED THAT THE PILOT'S TRACKING PERFORMANCE DETERIORATED MARKEDLY AT ACCELERATIONS GREATER THAN ABOUT 4G WHEN CONTROLLING A LIGHTLY DAMPED VEHICLE. THE TENTATIVE CONCLUSION WAS ALSO REACHED THAT REGARDLESS OF THE AIRFRAME DYNAMICS INVOLVED, THE PILOT FEELS THAT IN ORDER TO HAVE THE SAME LEVEL OF CONTROL OVER THE VEHICLE, AN INCREASE IN THE VEHICLE DYNAMIC STABILITY WAS REQUIRED WITH INCREASES IN THE MAGNITUDES OF THE ACCELERATION IMPRESSED UPON THE PILOT.

IN ANOTHER PHASE, BOUNDARIES OF HUMAN TOLERANCE OF ACCELERATION WERE ESTABLISHED FOR ACCELERATION FIELDS SUCH AS MIGHT BE ENCOUNTERED BY A PILOT FLYING AN ORBITAL VEHICLE. A SPECIAL PILOT RESTRAINT SYSTEM WAS DEVELOPED TO INCREASE HUMAN TOLERANCE TO LONGITUDINAL DECELERATIONS. THE RESULTS OF THE TESTS SHOWED THAT HUMAN TOLERANCE OF LONGITUDINAL DECELERATION FORCES WAS CONSIDERABLY IMPROVED THROUGH USE OF THE SPECIAL RESTRAINT SYSTEM.

A COMPARATIVE EVALUATION WAS MADE, IN ANOTHER PHASE OF THE INVESTIGATION, OF THE THREE-AXIS TYPE OF SIDE-ARM CONTROLLER AND THE TWO-AXIS TYPE IN COMBINATION WITH THE PEDALS FOR YAW CONTROL. DURING THE TESTS, THE DIFFICULTY OF BLENDING AND APPLYING THREE CONTROL INPUTS WITH ONE HAND USING THE THREE-AXIS CONTROLLERS WAS REPEATEDLY POINTED OUT BY THE EVALUATION PILOTS; AS A RESULT, THEY WERE UNANIMOUS IN THEIR PREFERENCE OF THE TWO-AXIS TWO-PEDAL CLASS OF CONTROLLERS.

CREEER, B.Y., STEWART, J.D., MERRICK, R.B., AND DRINKWATER, F.J.III. A PILOT OPINION STUDY OF LATERAL CONTROL REQUIREMENTS FOR FIGHTER-TYPE AIRCRAFT. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MEMORANDUM 1-29-59A, MAR. 1959.

* ABSTRACT *

AS PART OF A CONTINUING NASA PROGRAM OF RESEARCH ON AIRPLANE HANDLING QUALITIES, A PILOT OPINION INVESTIGATION HAS BEEN MADE ON THE LATERAL CONTROL REQUIREMENTS OF FIGHTER AIRCRAFT FLYING IN THEIR COMBAT SPEED RANGE. THE INVESTIGATION WAS CARRIED OUT USING A STATIONARY FLIGHT SIMULATOR AND A MOVING FLIGHT SIMULATOR, AND THE FLIGHT SIMULATOR RESULTS WERE SUPPLEMENTED BY RESEARCH TESTS IN ACTUAL FLIGHT.

A FLIGHT SIMULATOR STUDY WAS BASED ON THE PRESUMPTION THAT THE PILOT RATES THE ROLL CONTROL OF AN AIRPLANE PRIMARILY ON A SINGLE-DEGREE-OF-FREEDOM BASIS; THAT IS, CONTROL OF ANGLE OF ROLL ABOUT THE AIRCRAFT BODY AXIS BEING OF FIRST IMPORTANCE. FROM THE ASSUMPTION OF A SINGLE DEGREE OF FREEDOM SYSTEM, IT FOLLOWS THAT THERE ARE TWO FUNDAMENTAL PARAMETERS WHICH GOVERN THE AIRPLANE ROLL RESPONSE, NAMELY THE ROLL DAMPING EXPRESSED AS A TIME CONSTANT AND ROLL CONTROL POWER IN TERMS OF ROLL ACCELERATION. THE SIMULATOR STUDY RESULTED IN A CRITERION IN TERMS OF THESE TWO PARAMETERS WHICH DEFINES SATISFACTORY, UNSATISFACTORY, AND UNACCEPTABLE ROLL PERFORMANCE FROM A PILOT OPINION STANDPOINT. THE MOVING SIMULATOR RESULTS WERE SUBSTANTIATED BY THE IN-FLIGHT INVESTIGATION.

THE DERIVED CRITERION WAS COMPARED WITH THE ROLL PERFORMANCE CRITERION BASED UPON WING TIP HELIX ANGLE AND ALSO WITH OTHER ROLL PERFORMANCE CONCEPTS WHICH CURRENTLY INFLUENCE THE ROLL PERFORMANCE DESIGN OF MILITARY FIGHTER AIRCRAFT FLYING IN THEIR COMBAT SPEED RANGE.

CRAIGIE, R.J. DIRECTIONAL CONTROL OF ACCELERATIVE FORCES IN CENTRIFUGE BY SYSTEM OF GIMBALS. JOURNAL OF AVIATION MEDICINE, VOLUME 27, PAGES 505-511, DECEMBER 1956.

* ABSTRACT *

IN HUMAN CENTRIFUGE STUDIES, BY SUSPENDING THE SUBJECT IN A CONTROLLABLE DOUBLE GIMBAL SYSTEM, AS COMPARED TO PLACING HIM ON A FREELY SWINGING PLATFORM, THE FOLLOWING BENEFICIAL RESULTS ARE DERIVED:

1. IT IS POSSIBLE TO VECTOR OUT THE TANGENTIAL ACCELERATION DUE TO THE ANGULAR ACCELERATION OF THE CENTRIFUGE ARM BY PROPER MOVEMENT OF THE INNER GIMBAL, SO THAT IT IS NOT FELT AS A TRANSVERSE G COMPONENT OF THE RESULTING G. THE OCULOGYRAL ILLUSIONS OF THE GONDOLA TUMBLING ARE LESS UNPLEASANT AND LESS DISORIENTING THAN THE OCULOGRATIC ILLUSIONS CAUSED BY THE ROTATING RESULTANT G VECTOR ON A NONGIMBALED CENTRIFUGE RIDE.

2. THE OVERTHOOTING AND OSCILLATING OF THE FREELY SWINGING PLATFORM ARE PRACTICALLY ELIMINATED BY THE TIGHT CONTROL PLACED ON THE OUTER GIMBAL DURING ITS MOVEMENT.

3. THE ABILITY OF THE GIMBALS TO OPERATE SINGLY OR IN COMBINATION ALLOWS FOR THE GREAT VARIETY OF JOSTLING G PATTERNS TYPICAL OF UNCONTROLLED AIRCRAFT. THESE MAY BE DUPLICATED AS OFTEN AS NECESSARY TO GAIN A STATISTICAL EVALUATION OF THE TOLERANCE OF THE AVERAGE PILOT UNDER SUCH CONDITIONS.

4. CATAPULT G PATTERNS MAY BE PARTIALLY REPRODUCED BY PROPER POSITIONING OF THE GIMBALS. VALUABLE INFORMATION FOR A PRELIMINARY STUDY ON THE CATAPULT CAN THEREFORE BE OBTAINED PRIOR TO ACTUAL CATAPULTING, UNDER MORE PRECISE CONTROL CONDITIONS, AND AT A MUCH REDUCED COST PER RUN.

5. THE GIMBAL SYSTEM MAY OFFER THE MEANS WHEREBY A PILOT, WITH THE AID OF SUITABLE INSTRUMENTATION, MAY ACTUALLY CONTROL HIS OWN RIDE UNDER VARIOUS CONDITIONS. (AUTHOR)

CURRY, F.E., YOUNG, L.R., HOFFMAN, W.C. AND KUGEL, D.L. A PILOT MODEL WITH VISUAL AND MOTION CUES. AIAA VISUAL AND MOTION SIMULATION CONFERENCE PROCEEDINGS, DAYTON, OHIO, APRIL 26-28, 1976, P. 50-549

* ABSTRACT *

A MODEL OF PILOT CONTROL PERFORMANCE IS DEVELOPED TO ACCOUNT FOR THE EFFECTS OF MOTION CUES AND EXTERNAL VISUAL (VMC) CUES. THE STARTING POINT FOR THE MODEL IS THE OPTIMAL CONTROL MODEL OF THE HUMAN OPERATOR, WHICH HAS BEEN WELL VALIDATED IN FIXED-BASE IMC (E.G., INSTRUMENT CUES) SITUATIONS. THE FIRST GOAL WAS TO INCORPORATE MOTION CUES BY AUGMENTING THE CONTROLLED-STATE VECTOR WITH THE DYNAMIC DESCRIPTION OF THE VESTIBULAR SENSORY ORGANS (SEMI-CIRCULAR CANAL AND OTOLITH). COMPARISON OF THE MODEL PREDICTIONS WITH EXPERIMENTAL RESULTS OF MOTION-ONLY TRACKING INDICATES THAT THE NOISE/SIGNAL RATIO FOR THE VESTIBULAR MEASUREMENTS CAN BE MODELED AS APPROXIMATELY -18 DB.

NAVTRAEQUIPCEN IH-298

THIS NEW MODEL WAS APPLIED TO A VTOL HOVERING TASK AND DID AN EXCELLENT JOB OF DESCRIBING THE CONTROL PERFORMANCE WITH WITHOUT MOTION CUES, BOTH ON AN ABSOLUTE AND RELATIVE BASIS. THE DIFFERENCE BETWEEN IMC AND VMC VISUAL CUES WAS ACCOUNTED FOR IN THE MODEL BY DECREASING THE QUADRATIC PENALTY ON ROLL RATE (I.E., HIGHER ROLL RATES ARE ALLOWED). THE MODEL PROVIDES A GOOD DESCRIPTION OF CONTROL PERFORMANCE WITH AND WITHOUT MOTION AND VMC CUES, AND PREDICTS THE CHANGE IN SCANNING BEHAVIOR OBSERVED UNDER THESE CONDITIONS.

CUSTER, L.L. - AVIATION TRAINING MACHINE
PATENT NO. 2,063,231
FILED SEP. 15, 1930 GRANTED DEC. 8, 1936

NR ABSTRACT

CUTLER, A.E. 'ENVIRONMENTAL REALISM IN FLIGHT SIMULATORS'.
J. INST. ELECTRON. RAD. ENGRS., 1966, 31, 5-16. QUOTED AFTER HUD-
CLESTON (1966)

* ABSTRACT *

A SUMMARY OF EXPERIENCE FROM A LEADING MANUFACTURER'S VIEWPOINT. THE LACK OF COCKPIT MOTION CUES IN EARLY SIMULATORS GAVE RISE TO EXCESSIVE PILOT SCRUTINY OF INSTRUMENT BEHAVIOR FIDELITY. IN ACHIEVING MOTION PERCEPTION (WITH VISUAL HELP) LINEAR POSITION AND VELOCITY, AND ANGULAR POSITION, ARE NOT USEFUL; CHANGES (EVEN TRANSIENTS) IN LINEAR ACCELERATION, AND IN ANGULAR VELOCITY AND ACCELERATION, ARE MOST USEFUL. AN IMPRESSION OF SKAY OR SURGE CAN BE GIVEN BY LEANING RESIDUAL ROLL OR PITCH DISPLACEMENTS FOLLOWING ROLL OR PITCH MANEUVER ACCELERATIONS. YAW IS NOT VERY IMPORTANT, SINCE IT NORMALLY OCCURS IN COMBINATION WITH OTHER MOTIONS TO WHICH THE BODY IS MORE SENSITIVE.

CUTTS, S.C. 'A STUDY OF TURBULENCE SIMULATION'. LINK GROUP SYSTEMS DIVISION, GENERAL PRECISION, INC. BINGHAMTON. ENGINEERING REPORT NO. 854, NOVEMBER, 1967.

* ABSTRACT *

A TURBULENCE SIMULATION STUDY HAS BEEN COMPLETED AND THIS DOCUMENT DESCRIBES THE RESULTS OF THAT STUDY. THE APPROACH LINK TO CONSTRUCT TURBULENCE AS A CONTINUOUS GUSTING VELOCITY OF THE FORM:

$S(+)$ E (M) (AR SIN NWT + BM COS NWT)

N=1 WHERE $W=K/V$ (K=CONSTANT)
 AN, BN=RANDOM
 V=FORWARD AIRSPEED
 GAUSSIAN VARIABLES

BY SUITABLY GENERATING $A(N)$ AND $B(N)$, $S(T)$ CAN BE MADE TO HAVE THE SAME POWER SPECTRAL CHARACTERISTICS OF TURBULENCE AS SPECIFIED IN NASA REPORT NO. 1272 (REFERENCE). FIGURE 4, WITHIN THE MAIN TEXT, SHOWS THE INTEGRATION OF THE TURBULENCE GENERATION INTO THE MAIN COMPUTATIONAL SYSTEM AND IS OUR PROPOSED METHOD FOR IMPLEMENTATION IN A SIMULATOR. IT IS PRESENTLY PLANNED TO MORE THOROUGHLY EVALUATE THIS APPROACH IN A TEST CONFIGURATION ON A GP-IV COMPUTER. THE RESULTS OF THIS TEST WILL BE FORWARDED AS SOON AS AVAILABLE.

CYRLS, M.L. ENERGY CONSERVATION THROUGH THE OPTIMIZATION OF HYDRAULIC POWER SUPPLIES FOR THE SIX DEGREE OF FREEDOM MOTION SYSTEM. FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY REPORT: AFHRL-TR-77-7, WILLIAMS AIR FORCE BASE, ARIZONA 85224, MAR. 1977.

* ABSTRACT *

THE OBJECTIVE OF THIS PROJECT WAS TO ESTIMATE THE APPROXIMATE HYDRAULIC FLUID FLOW REQUIREMENTS FOR THE SIX DEGREE OF FREEDOM MOTION SYSTEM OF THE TYPE SPECIFIED IN MIL-STD-1558 AND DETERMINE MEANS BY WHICH MOTION HYDRAULIC SUPPLIES CAN BE CUT, COMBINED, OR MADE MORE EFFICIENT. THIS PAPER DEFINES THE APPROACH, DATA COLLECTION, ANALYSIS, AND RESULTS OF THAT PROJECT.

CYRLS, M.L. METHOD FOR COMPENSATING TRANSPORT LAGS IN COMPUTER IMAGE GENERATION VISUAL DISPLAYS FOR FLIGHT SIMULATION. FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY REPORT: AFHRL-TR-77-6, MAR 1977.

* ABSTRACT *

THIS PAPER EXAMINES AN ANALYTICAL TECHNIQUE FOR SIMULTANEOUSLY COMPENSATING TRANSPORT DELAYS IN COMPUTER IMAGE GENERATION (CIG) VISUAL SYSTEMS, WHILE ELIMINATING HIGH FREQUENCY 'FILTER' EFFECTS.

CYRLS, M.L. ENGINEERING AND GEOMETRIC CONSTRAINTS OF A SIX DEGREE OF FREEDOM SYNERGISTIC PLATFORM MOTION SYSTEM. FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY REPORT: AFHRL-TR-77-5, WILLIAMS AIR FORCE BASE, ARIZONA, MAY 1977.

* ABSTRACT *

RECENT CONTROVERSY SURROUNDING THE TRAINING EFFECTIVENESS OF THE SIX DEGREE OF FREEDOM, SYNERGISTIC PLATFORM MOTION SYSTEM IS CENTERED ON SEVERAL ISSUES, ONE OF WHICH IS, SURPRISINGLY, JUST EXACTLY WHAT MOTION THE PLATFORM IS CAPABLE OF PRODUCING. THIS PAPER PRESENTS THE PRIMARY EQUATIONS AND CONSTRAINTS, AS WELL AS A NUMBER OF DERIVED CONSTRAINTS APPLICABLE TO THE ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT), A REPRESENTATIVE MOTION SYSTEM.

CYRUS, M.L. MOTION SYSTEMS ROLE IN FLIGHT SIMULATORS
FOR FLYING TRAINING
HUMAN RESOURCES LABORATORY (AFSC)
FLYING TRAINING DIVISION
WILLIAMS AFB, AZ, AUG. 1978.
REPORT: AFHRL-TR-78-39

* ABSTRACT *

THIS REPORT REVIEWS THE LITERATURE AS IT RELATES TO THE USE OF PLATFORM MOTION SYSTEMS IN FLIGHT SIMULATORS FOR FLYING TRAINING. MOTION IS DISCUSSED IN TERMS OF ITS EFFECT ON COMPENSATORY, PURSUIT, AND PRECOGNITIVE TASKS, WITHIN BOTH THE SIMULATOR AND TRANSFER CONTEXTS. ALTHOUGH BOTH SKILLED AND UNSKILLED BEHAVIOR IS ADDRESSED, THE FORMER IS EMPHASIZED. THE REPORT CONCLUDES THAT, FOR MOST TASKS, PLATFORM MOTION IS NOT REQUIRED TO PRODUCE RAPID, EFFICIENT, ECONOMICAL TRAINING, AND THAT OTHER LESS EXPENSIVE MEANS OF IMPARTING MOTION INFORMATION ARE EQUALLY VIABLE ALTERNATIVES AND RECOMMENDS:

(1) WHENEVER FEASIBLE AND AFFORDABLE, SIMULATOR SYSTEMS SHOULD BE EQUIPPED WITH THE LARGEST FIELD-OF-VIEW VISUAL SYSTEM CONSISTENT WITH MISSION REQUIREMENTS, AND

(2) SIMULATORS CAN (FOR MOST AIRCRAFT) BE SAFELY PROCURED WITHOUT A PLATFORM MOTION SYSTEM WITHOUT COMPROMISING TRAINING EFFECTIVENESS.

CYRUS, M.L. AND TEMPLETON, T.K. BUFFET SIMULATION FOR ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT). FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY REPORT, AFHRL-TR-77-4, WILLIAMS AIR FORCE BASE, ARIZONA, MAR. 1977.

* ABSTRACT *

THIS PAPER PRESENTS A MOTION/CONTROL LANDING BUFFET SIMULATION PACKAGE AS IMPLEMENTED ON THE ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT) LOCATED AT WILLIAMS AFB, ARIZONA. ALL PRIMARY BUFFET EFFECTS ARE INCLUDED. THE HIGH LEVEL OF PILOT ACCEPTANCE AND SUBJECTIVE REALISM INDICATE A SIMPLIFIED APPROACH TO BUFFET SIMULATION IS SUFFICIENT FOR TRAINING PURPOSES.

DANNESKILD, R.D.
 OBJECTIVE SCORING PROCEDURE FOR OPERATIONAL FLIGHT TRAINER PERFORMANCE, TECHNICAL REPORT SPECDEVCECEN 999-2-4. THE PSYCHOLOGICAL CORPORATION AND THE U.S. NAVY SPECIAL DEVICES CENTER PROJECT 20-A-13, FEB. 1955. (AD-110 925)

* ABSTRACT *

THIS REPORT CONTAINS AN ANALYSIS OF THE PROBLEM OF SCORING STUDENT PERFORMANCE IN FLIGHT TRAINING DEVICES AND REPORTS IN DETAIL THE RESULTS OF VARIOUS STUDIES OF THE PROBLEM. CHAPTER I IS A REVIEW OF THE HISTORY AND PROBLEMS OF FLIGHT GRADING. CHAPTER II POINTS UP SPECIFIC PROBLEMS TO BE SOLVED BY THE DESIGN OF SCORING INSTRUMENTS. CHAPTERS III, IV, V, AND VII PRESENT THE DETAILS OF THE RESEARCH AND SUMMARIZE THE FINDINGS. THE RESULTS GENERALLY INDICATE THAT:

1. THE TECHNIQUE FOR ASSESSING PILOT PERFORMANCE IN THE AIRCRAFT IS FEASIBLE FOR MEASURING STUDENT PROGRESS IN FLIGHT TRAINERS.
2. MECHANICAL OR AUTOMATIC SCORING METHODS ARE CUMBERSOME AND FAIL TO MEASURE TOTAL PERFORMANCE. FLIGHT PATH RECORDING INSTRUMENTS ARE OF VALUE AS AN ADJUNCT TO MANUAL GRADING FORMS USED BY INSTRUCTORS.
3. INSTRUCTOR SCORING INSTRUMENTS FOR BASIC INSTRUMENT FAMILIARIZATION AND PROCEDURES TRAINING IN THE SNU-8FT AND F9FE-8FT WERE DEVELOPED AND APPEAR IN THE APPENDIX.

J.S.W. DAVIDSEN, ET AL - CENTRIFUGE MOUNTED MOTION SIMULATOR
 PATENT NO. 3,196,557
 DATE FILED - AUGUST 28, 1961 DATE GRANTED - JULY 27, 1965

NO ABSTRACT

DAVIS, J. AND BEADSMORE, E.J. A MILITARY VIEW OF FLIGHT SIMULATION. IN PROCEEDINGS, TWO-DAY SYMPOSIUM ON FLIGHT TRAINING SIMULATORS FOR THE 70'S. 14/15 OCTOBER, 1970, THE ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 8BQ.

* ABSTRACT *

DISCUSSES THE NEW GENERATION OF FLIGHT SIMULATORS, KNOWN AS FULL MISSION SIMULATORS IN USE BY THE RAF AND RN. THEIR COMMENTS CONCERNING MOTION ARE CONTAINED IN THE FOLLOWING PARAGRAPH.

WE DO NOT WISH TO SAY MUCH ABOUT MOTION EXCEPT THAT OUR MISSION SIMULATORS EMBODY EITHER THREE OR FOUR DEGREES-OF-FREEDOM SYSTEMS. WE ARE NOT CONVINCED OF THE NEED FOR ALL SIX FREEDOMS IN FACT WE ARE NOT REALLY SATISFIED THAT A MOTION SYSTEM WITH MORE THAN THE STANDARD THREE DEGREES OF FREEDOM (ROLL, PITCH AND HEAVE) IS NECESSARY FOR A MILITARY SIMULATOR. HOWEVER, IN OUR FIGHTER-TYPE SIMULATORS WE REQUIRE RATHER NATURALLY, HIGHER ROLL RATES AND EXCURSIONS THAN DOES THE CIVIL OPERATOR. IN OUR FARRIER SIMULATOR WE WILL HAVE ROLL RATES AND EXCURSIONS IN EXCESS OF THOSE PROVIDED FOR THE SIX DEGREES-OF-FREEDOM MOTION PLATFORMS CURRENTLY IN BUILD. MISSION SIMULATORS HAVE, IN ADDITION A 'G' SYSTEM, COMPLEMENTARY TO THE MOTION SYSTEM, WHICH IS INTENDED TO ADD TO THE STIMULI RECEIVED BY THE PILOT DURING MANEUVERS INVOLVING BOTH POSITIVE AND NEGATIVE 'G'. THE PILOT'S SHOULDER AND LAP STRAPS ARE TIGHTENED DURING NEGATIVE 'G' MANEUVERS, AND THE EJECTOR SEAT PAN IS MOVED DURING POSITIVE 'G'.

M.F. DE BOY ET AL - TASK TRAINER
PATENT NO. 3,161,968
FILED FEB. 19, 1962 GRANTED DEC. 22, 1964

NO ABSTRACT

DE FLOREZ, L. - TRAINING APPARATUS
PATENT NO. 2,301,685
FILED AUG. 13, 1940 GRANTED NOV. 10, 1942

NO ABSTRACT

DEBERG, R.H., MCFARLAND, B.P. AND SHOWALTER, T.W. THE EFFECT OF SIMULATOR FIDELITY ON ENGINE FAILURE TRAINING IN THE KC-135 AIRCRAFT. AERONAUTICAL SYSTEMS DIVISION, UNITED STATES AIR FORCE, WRIGHT-PATTERSON AFB, OHIO. APRIL 26-28, 1976. PP. 83-87.

* ABSTRACT *
BECAUSE OF THE DANGERS ASSOCIATED WITH ENGINE FAILURES DURING TAKEOFF OF LARGE MULTI-ENGINE AIRCRAFT, FLIGHT SIMULATORS ARE USUALLY USED TO TRAIN PILOTS TO RECOVER FROM THIS FAILURE. AN ASSESSMENT OF THE EFFECTIVENESS OF THE TRAINING WAS MADE USING AN ENGINEERING FLIGHT SIMULATOR WITH KC-135A AIRCRAFT COMMANDERS AS A TEST SUBJECTS. THE AVAILABLE VISUAL SYSTEM AND MOTION SYSTEM CUEING CAPABILITIES OF THE ENGINEERING SIMULATOR WERE RESTRICTED TO PRODUCE FOUR COMBINATIONS REPRESENTING

CURRENT TRAINING HARDWARE: (A) VISUAL SYSTEM CUES ONLY, (B) MOTION SYSTEM CUES ONLY, (C) VISUAL SYSTEM AND MOTION CUES, AND (D) NO VISUAL SYSTEM OR MOTION SYSTEM CUES. ONE SUBJECT GROUP WAS TRAINED TO RECOVER FROM ENGINE FAILURE IN EACH OF THESE CUEING SITUATIONS. ALL RESTRICTIONS TO THE CUEING OF THE ENGINEERING SIMULATOR WERE THEN REMOVED, AND TRAINING EFFECTIVENESS OF THE FOUR CANDIDATE SYSTEMS WAS ASSESSED BY MEASURING PILOT PERFORMANCE IN THE UNRESTRICTED ENGINEERING SIMULATOR. RESULTS WERE ANALYZED BY A FACTORIAL ANALYSIS OF VARIANCE. RESULTS INDICATE: (A) THE SUPERIORITY OF TRAINING EFFECTIVENESS WITH VISUAL SIMULATOR SYSTEMS, (B) THE ENHANCEMENT OF TRAINING EFFECTIVENESS BY INCLUDING A MOTION SYSTEM IN THE TRAINING SIMULATOR, AND (C) THE SYNERGISTIC IMPROVEMENT IN TRAINING USING BOTH MOTION AND VISUAL SYSTEMS TOGETHER. THIS EXPERIMENT IS THE FIRST OF A SERIES WHAT WILL INVESTIGATE SIMULATION CUEING EFFECTIVENESS.

R.C. DEHREL - FLIGHT TRAINING APPARATUS FOR COMPUTING FLIGHT CONDITIONS AND SIMULATING REACTION OF FORCES ON PILOTS
PATENT NO. 2,687,580
FILED MAY 25, 1948 GRANTED AUG 31, 1954

NO ABSTRACT

DEILY, W.H., GLASSMAN, I., AND HOUGHTON, D.B. A DYNAMIC AIRCRAFT SIMULATOR FOR STUDY OF HUMAN RESPONSE CHARACTERISTICS. 'THE FRANKLIN INSTITUTE LABORATORIES', PHILA. PA, TECHNICAL REPORT F-2169, 30 SEP 1952.

* ABSTRACT *
THIS REPORT COVERS THE DESIGN AND CONSTRUCTION OF A DYNAMIC SIMULATOR OF AN AIRCRAFT IN FLIGHT IN WHICH 'HUMAN FREQUENCY RESPONSES' TO VISUAL SIGNALS MAY BE MEASURED FOR THE PURPOSE OF DETERMINING OPTIMUM CHARACTERISTICS OF AN AIRCRAFT'S CONTROLS.

THE DYNAMIC SIMULATOR COMPRISES AN AIRCRAFT COCKPIT, A PROGRAM UNIT WHICH PRESENTS VISUAL INPUT STIMULI ON A CATHODE-RAY TUBE IN VIEW OF THE PILOT, AND ELECTRONIC ANALOG COMPUTER WHICH COMPUTES THE AIRCRAFT EQUATIONS OF MOTION AND RESULTANT STIMULI (TARGET) MOTIONS, AND A RECORDER TO RECORD PILOT RESPONSES AND OTHER DESIRED QUANTITIES. THE AIRCRAFT SIMULATED IS THE F-8CA JET FIGHTER.

VALIDATION OF THE SIMULATOR INDICATES THAT THE DEVICE 'FLIES' LIKE THE F-8CA.

NAVTRAEQUIPCEN IH-298

DEMAREE, R., NORMAN, D. AND MATHENY, G. 'AN EXPERIMENTAL PROGRAM FOR RELATING TRANSFER OF TRAINING TO PILOT PERFORMANCE AND DEGREE OF SIMULATION'. NAVTRAEVCEN 1388-1 U.S. NAVAL TRAINING DEVICE CENTER, FORT WASHINGTON, NEW YORK, JUNE 1965.

* ABSTRACT *

THE RELATIONSHIP BETWEEN THE DEGREE OF SIMULATION AND THE RESULTING TRANSFER OF TRAINING FOR PILOTING TASKS IN FLIGHT SIMULATORS REPRESENTS AN AREA OF INVESTIGATION IN WHICH RELATIVELY FEW STUDIES HAVE BEEN CONDUCTED TO DATE AND CONSEQUENTLY, FOR WHICH LITTLE EMPIRICAL DATA IS AVAILABLE. THE UDFFT (UNIVERSAL DIGITAL OPERATIONAL FLIGHT TRAINER TOOL) PROVIDES AN OPPORTUNITY FOR PILOT TRAINING RESEARCH TO BE CONDUCTED IN WHICH SPECIFIC MODIFICATIONS OR REDUCTIONS IN THE DEGREES OF SIMULATION ARE INTRODUCED AS EXPERIMENTAL VARIABLES IN AN ORGANIZED PROGRAM OF STUDIES OF THE TRANSFER OF TRAINING OF PILOTING SKILLS AND TECHNIQUES.

INITIAL INVESTIGATIONS AND A PILOT PERFORMANCE STUDY HAVE BEEN CONDUCTED WITH RESPECT TO THE USE OF THE UDFFT COMPUTER IN CONJUNCTION WITH A REAL-TIME INPUT-OUTPUT CAPABILITY AND TO AN INSTRUMENTED JET FIGHTER COCKPIT. THE RATIONALE, METHODOLOGY AND OUTLINE FOR A SERIES OF PILOT TRAINING RESEARCH STUDIES HAVE BEEN DEVELOPED IN CONJUNCTION WITH THE DETERMINATION OF EFFECTIVE MEANS FOR USE OF THE UDFFT, INCLUDING THE RECORDING AND COMPUTATION OF OBJECTIVE PERFORMANCE MEASURES.

DEMSEY, T.K. AND LEATHERWOOD, J.D. VIBRATION SIMULATOR STUDIES FOR THE DEVELOPMENT OF PASSENGER RIDE COMFORT CRITERIA. NASA TM-X-3295, 1975.

* ABSTRACT *

THE AUTHORS DESCRIBE AN EXPERIMENT UNDERTAKEN TO FIND THE TOTAL DISCOMFORT ASSOCIATED WITH VEHICLE VIBRATION. THE PROGRAM USES A THREE DEGREE-OF-FREEDOM VIBRATION SIMULATOR TO DETERMINE THE EFFECTS OF MULTI-FREQUENCY AND MULTI-AXIS VIBRATION INPUTS ON COMFORT. THE APPROACH TO MULTI-FREQUENCY VIBRATION INCLUDES A SEPARATE CONSIDERATION OF THE DISCOMFORT ASSOCIATED WITH EACH FREQUENCY OR BAND OF THE TOTAL SPECTRUM, AND A SUBSEQUENT EMPIRICAL WEIGHTING OF THE DISCOMFORT COMPONENTS OF THESE FREQUENCY BANDS WHEN IN RANDOM COMBINATIONS. THE RESULTS ARE IN THE FORM OF EQUAL DISCOMFORT CURVES THAT SPECIFY THE DISCOMFORT RESPONSE TO INCREASES IN ACCELERATION LEVEL FOR EACH FREQUENCY INVESTIGATED. MORE IMPORTANTLY, THE RESULTS PROVIDE A METHOD FOR ADDING THE DISCOMFORT ASSOCIATED WITH SEPARATE FREQUENCIES TO GIVE A TOTAL TYPIFICATION OF THE DISCOMFORT OF A RANDOM SPECTRUM OF VIBRATION.

CAMPSEY, T.K. AND LEATHERWOOD, J.D. VIBRATION SIMULATOR STUDIES FOR THE DEVELOPMENT OF PASSENGER RIDE COMFORT CRITERIA. NASA LANGLEY RESEARCH CENTER, HAMPTON, VA. NASA TM-X-3295, 1975.

* ABSTRACT *

AN EXPERIMENT WAS UNDERTAKEN TO FIND THE TOTAL DISCOMFORT ASSOCIATED WITH VEHICLE VIBRATION. A THREE DEGREES-OF-FREEDOM VIBRATION SIMULATOR WAS USED TO DETERMINE THE EFFECTS OF MULTI-FREQUENCY AND MULTI-AXIS VIBRATION ON COMFORT. THE APPROACH TO MULTI-FREQUENCY VIBRATION INCLUDED A SEPARATE CONSIDERATION OF THE DISCOMFORT ASSOCIATED WITH EACH FREQUENCY OR BAND OF THE TOTAL SPECTRUM, AND A SUBSEQUENT EMPIRICAL WEIGHTING OF THE DISCOMFORT COMPONENTS OF THESE FREQUENCY BANDS WHEN IN VARIOUS RANDOM COMBINATIONS. THE RESULTS ARE IN THE FORM OF EQUAL DISCOMFORT CURVES THAT SPECIFY THE DISCOMFORT RESPONSE TO INCREASES IN ACCELERATION LEVEL FOR EACH FREQUENCY INVESTIGATED. THE RESULTS PROVIDE A METHOD FOR ADDING THE DISCOMFORT ASSOCIATED WITH SEPARATE FREQUENCIES TO GIVE A TOTAL PICTURE OF THE DISCOMFORT OF A RANDOM SPECTRUM OF VIBRATION.

CEREVYANKO, A. Y., AND MYLIKIN, V.G. 'BIOLOGICAL EFFECTS OF GRAVITATIONAL ACCELERATION'. TT 64/41200, AUG. 1964 U.S. DEPT. OF COMMERCE, JPRS 25, 929.

NO ABSTRACT GIVEN

DEVEREAUX, T.E., GALLOWAY, R.T., COSTELLO, W.J. AND DINEEN, T.G. 'FLIGHT FIDELITY EVALUATION OF THE A-4M OPERATIONAL FLIGHT TRAINER (DEVICE 2F 108)'. NAVAL AIR TEST CENTER, PATUXENT RIVER. REPORT NO. NATC-SA-5R-76, FEBRUARY 1976. AD NO. B 009 808L

* ABSTRACT *

THE A-4M OPERATIONAL FLIGHT TRAINER, DEVICE 2F-108, UNIT 1 WAS EVALUATED FOR SIMULATION FIDELITY TO A-4M AIRPLANE FLYING QUALITIES AND PERFORMANCE CHARACTERISTICS. THE EVALUATION TEAM CONDUCTED TESTS AND PARTICIPATED IN DEVELOPMENT OF DEFICIENCY CORRECTIONS AT THE CONTRACTOR'S FACILITY AND THEN PARTICIPATED IN FINAL ACCEPTANCE TESTING AND VALIDATION OF UNIT 1 AT MCAS, YUMA, ARIZONA. FLIGHT TEST TECHNIQUES WERE UTILIZED IN THE SIMULATOR TO ASSESS FLIGHT FIDELITY AND ASSIST IN THE ITERATIVE DEFICIENCY CORRECTION PROCESS. BASELINE DATA WERE OBTAINED FROM PUBLISHED REPORTS AND FROM FLIGHT TESTS CONDUCTED WITH SEVERAL A-4M AIRPLANES. THE INITIAL TESTS REVEALED SEVERAL SERIOUS DEFICIENCIES, INCLUDING LATERAL AND LONGITUDINAL PILOT INDUCED OSCILLATION TENDENCIES IN CLOSED LOOP TASKS, UNREPRESENTATIVE STALL CHARACTERISTICS, INCORRECT CONTROL SYSTEM CHARACTERISTICS AND UNSATISFACTORY MOTION AND

PLUFFET CUES. TEST PILOTS AND FLIGHT TEST ENGINEERS FROM THE NAVAL AIR TEST CENTER ASSISTED THE CONTRACTOR (SECOR) OVER AN 8 MONTH PERIOD IN DEVELOPING CORRECTIONS TO THESE DEFICIENCIES. AS A RESULT OF THIS EFFORT, THE FLYING QUALITIES AND PERFORMANCE CHARACTERISTICS OF DEVICE 2F-108 ARE NOW REPRESENTATIVE OF THE A-4M AIRPLANE WITH THE EXCEPTION OF TWO DEFICIENCIES, AND DEVICE 2F-108 FLIGHT FIDELITY IS SATISFACTORY FOR OPERATIONAL USE IN THE TRAINING OF A-4M FLIGHT CHARACTERISTICS. ONE PART II DEFICIENCY, LACK OF LATERAL CG SHIFT DUE TO FUEL SLOSH, SHOULD BE CORRECTED AS SOON AS PRACTICAL. ONE PART III DEFICIENCY, LACK OF FIDELITY OF CG POSITION IN DEVICE 2F-108 TO THE A-4M AIRPLANE WITH ECP 1120 INCORPORATED, SHOULD BE CORRECTED IF FEASIBLE AND AVOIDED IN FUTURE DESIGNS. THE LONGITUDINAL AND LATERAL CONTROL SYSTEM MECHANICAL CHARACTERISTICS DATA FOR THE A-4M AIRPLANE PRESENTED IN THIS REPORT SHOULD BE UTILIZED AS REFERENCE VALUES TO AUGMENT EXISTING STANDARDIZED TEST PROCEDURES FOR DEVICE 2F-108 CONTROL SYSTEM ALIGNMENT.

DICHGANS, J., HELD, R., YOUNG, L.R. AND BRANDT, T.H.
MOVING VISUAL SCENES INFLUENCE THE APPARENT DIRECTION OF GRAVITY, 'SCIENCE' 179: 1217 - 1219 1972.

* ABSTRACT *
WHEN AN OBSERVER VIEWS A WIDE-ANGLED DISPLAY ROTATING AROUND HIS LINE OF SIGHT, HE BOTH FEELS HIS BODY TILTED AND SEES A VERTICAL STRAIGHT EDGE TILTED OPPOSITE TO THE MOVING STIMULUS. DISPLACEMENT OF THE PERCEIVED VERTICAL INCREASES WITH STIMULUS SPEED TO REACH A MAXIMUM (AVERAGING 15 DEGREES) AT 30 DEGREES PER SECOND.

DICHGANS, J.M. AND BRANDT, T.H., OPTOKINETIC MOTION SICKNESS AND PSEUDO-CORIBLIS EFFECTS INDUCED BY MOVING VISUAL STIMULI, ACTA OTOLARYNG 76 (1973) 339-348.

* ABSTRACT *
PSEUDO-CORIBLIS EFFECTS (PCE) AND OPTOKINETIC MOTION SICKNESS ARE ELICITED BY BENDING THE HEAD OUT OF THE AXIS OF ROTATION OF A CIRCULAR VISUAL SURROUND WHEN THAT MOVING SURROUND INDUCES THE ILLUSION OF SELF-ROTATION. WITH RESPECT TO TILT SENSATION AND VEGETATIVE SYMPTOMS, OPTOKINETIC PCE CORRESPOND TO VESTIBULAR CORIBLIS EFFECTS (CE) THAT ARISE FROM SIMILAR HEAD MOVEMENTS WHEN THE BODY IS ACTUALLY ROTATING. QUANTITATIVELY, PCE ARE OF SMALLER MAGNITUDE THAN CE AND SATURATE AT LOWER VELOCITIES OF STIMULATION (90-120 DEGREES PER SECOND). PCE, DEPENDING ON THE ILLUSORY SENSATION OF SELF-ROTATION (CIRCULARVECTION, CV), SHARE ITS PROLONGED TIME COURSE AFTER STIMULUS ONSET AND TERMINATION, ITS RELATION TO STIMULUS VELOCITIES AND ITS DEPENDENCY ON STIMU.

LUS AREA WITH PREDOMINANCE OF THE RETINAL PERIPHERY. OPTOKINETIC INFLUENCES ON VESTIBULAR CE DEPEND ON THE DIRECTION AND SPEED OF THE MOVING VISUAL STIMULUS AND RESULT IN EITHER INHIBITION OR FACILITATION OF APPARENT TILT AND NAUSEA.

DIEHL, A.E. AND RYAN, L.E. CURRENT SIMULATOR SUBSTITUTION PRACTICES IN FLIGHT TRAINING. 'TRAINING ANALYSIS AND EVALUATION GROUP RPT.' 43, FEB 1977.

* ABSTRACT *

MOTION SYSTEM COMPARISONS - THE RESULTS SHOWN IN TABLE 13 OF THIS REPORT TEND TO INDICATE THAT DEVICES WHICH EMPLOYED HIGH FIDELITY MOTION PLATFORMS ACHIEVED MORE EFFECTIVE SYLLABUS REDUCTION THAN THOSE DEVICES WHICH DID NOT EMPLOY SUCH SYSTEMS. MEDIAN SYLLABUS REDUCTIONS WERE 42 PERCENT FOR MOTION EQUIPPED DEVICES AS COMPARED TO 16 PERCENT FOR DEVICES WHICH LACKED MOTION. THE FLIGHT SUBSTITUTION RATIOS 1.0 AND 1.2 ALSO IMPLY SUPERIORITY OF MOTION EQUIPPED DEVICES. HOWEVER, PERSONAL COMMUNICATION WITH THE AUTHORS INDICATE THAT SOME CAUTION SHOULD BE TAKEN WITH THIS INTERPRETATION AS SOME OF THE POSITIVE RESULTS TOWARDS THE MOTION SYSTEMS MAY HAVE BEEN PRODUCED BY THE GREATER INTEREST AND EFFORT EXPENDED ON THE MORE COMPLEX AND EXPENSIVE DEVICES. FOR INSTANCE, SOME SIMULATOR TRAINING PROGRAMS WERE SUBJECT TO INSTRUCTIONAL SYSTEMS DESIGN (ISD) AND COMPARED TO OTHERS THAT WERE NOT UNDER ISD MANAGEMENT.

D'ELDONNE, J.E., PARRISH, R.V. AND BARDUSCH, R.E. AN ACTUATOR EXTENSION TRANSFORMATION FOR A MOTION SIMULATOR AND AN INVERSE TRANSFORMATION APPLYING NEWTON-RAPHSON'S METHOD. NASA 'TECHNICAL NOTE' TN-D-7067, NOVEMBER 1972.

* ABSTRACT *

A SET OF EQUATIONS WHICH TRANSFORM POSITION AND ANGULAR ORIENTATION OF THE CENTROID OF THE PAYLOAD PLATFORM OF THE SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR AT THE LANGLEY RESEARCH CENTER INTO EXTENSIONS OF THE SIMULATORS ACTUATORS HAS BEEN DERIVED AND IS BASED ON A GEOMETRICAL REPRESENTATION OF THE SYSTEM. AN ITERATIVE SCHEME - NEWTON-RAPHSON'S POSITION AND ANGULAR ORIENTATION OF THE CENTROID OF THE PAYLOAD PLATFORM WHEN THE MAGNITUDE OF THE ACTUATOR EXTENSIONS IS KNOWN. SUFFICIENT ACCURACY IS OBTAINED BY USING ONLY ONE NEWTON-RAPHSON ITERATION PER INTEGRATION STEP OF THE REAL-TIME ENVIRONMENT.

DORIE, T.G. MOTION SICKNESS DURING FLYING TRAINING. 'AGARD CONFERENCE PROCEEDINGS' SERIES NO. 2, SEPT. 1965, PP. 23-32.

* ABSTRACT *

OVER THE YEARS, MOTION SICKNESS HAS CONTINUED TO PRESENT A PROBLEM DURING FLYING TRAINING. MANY STUDENT AIRCREW HAVE BEEN REMOVED FROM TRAINING, PARTICULARLY AT THE BASIC STAGE, BECAUSE OF THIS CONDITION. MANY OTHERS, WHOSE TRAINING HAS BEEN HALTED BECAUSE OF A FAILURE TO MAKE PROGRESS IN THE AIR, HAVE HAD MOTION SICKNESS AS AN IMPORTANT UNDERLYING FACTOR. APART FROM THESE FAILURES, HOWEVER, A SIGNIFICANT NUMBER OF STUDENTS EXPERIENCE AIRSICKNESS TO SUCH A DEGREE AS TO ALTER THE PATTERN OF THEIR TRAINING. AT BEST, THE INSTRUCTOR HAS TO STOP MANEUVERS INDUCING SICKNESS, WITH A CONSEQUENT REDUCTION IN TRAINING EFFECTIVENESS ON THAT SORTIE AND AT WORST HE HAS TO ABANDON THE SORTIE. IT WAS THIS WASTAGE OF FLYING TRAINING TIME WHICH PROMPTED THIS STUDY. IN THE FIRST PLACE, TO SEE IF IT WAS POSSIBLE TO ASSESS AN INDIVIDUAL'S SUSCEPTIBILITY TO MOTION SICKNESS AND SECONDLY TO TRY TO REDUCE THE INCIDENCE OF THE CONDITION BY SOME FORM OF GROUND VESTIBULAR EXERCISE.

IT SEEMS LIKELY, HOWEVER, THAT PRIOR SELECTION DOES NOT HOLD OUT MUCH HOPE AS A MEANS OF AVOIDING THE WASTAGE OF FLYING TRAINING TIME DUE TO MOTION SICKNESS. IT IS FELT THAT ANY SUCCESS WHICH MIGHT BE FORTHCOMING, LIES ALONG THE PATH OF INDUCED ACCLIMATISATION BEFORE AND IN THE EARLY STAGES OF FLYING TRAINING. AT A TIME WHEN THE COST OF FLYING HOURS IS VERY HIGH INDEED, EVERY EFFORT SHOULD BE MADE TO REDUCE THE INCIDENCE OF THIS WASTEFUL ASPECT OF FLYING TRAINING.

DALEZAL, F. AND HELD, R., 'TWO COMPONENTS OF VISUALLY-INDUCED TILT DURING ROTARY FIELD MOTION', ABSTRACT OF PAPER PRESENTED AT E.P.A. MEETING, NEW YORK, NY, APRIL 1975.

NO ABSTRACT YET

DBLKAS, C.B. AND STEWART, J.D. 'EFFECT OF COMBINED LINEAR AND OSCILLATORY ACCELERATION ON PILOT ATTITUDE-CONTROL CAPABILITIES' NASA TN-D-2710, 1965.

* ABSTRACT *

DATA ARE PRESENTED TO SHOW THE EFFECTS OF SUPERIMPOSING VIBRATION AT 11 CYCLES PER SECOND ON STEADY LINEAR ACCELERATION ON THE TRACKING ABILITY OF A HUMAN PILOT IN A STABILITY AND RATE AUGMENTED VEHICLE WITH DYNAMICS TYPICAL OF A LARGE HIGH THRUST ROCKET. THE LINEAR ACCELERATION RANGED FROM 1 TO 3.5 G AND THE OSCILLATORY STRESSES VARIED FROM 0 TO + OR - 3.0 G AT

11 CPS. A RANDOM-APPEARING COMPENSATORY TRACKING PROBLEM WAS PRESENTED TO THE PILOT IN THE PITCH PLANE, ALTHOUGH THE PILOT CONTROLLED BOTH PITCH AND YAW. NO ATTEMPT WAS MADE IN THIS STUDY TO SIMULATE ADDITIONAL PILOT TASKS SUCH AS MONITORING OF CRITICAL LAUNCH VEHICLE AND SPACECRAFT PERFORMANCE AND STATUS DISPLAYS WHICH WOULD BE REQUIRED IN THE REAL SITUATION. VARIOUS DAMPER FAILURE SITUATIONS WERE INVESTIGATED AND CERTAIN CHARACTERISTICS DUE TO AUTOPILOT NONLINEARITIES WERE STUDIED. EFFECTS ON THE TRACKING EFFICIENCY OF DIVIDING THE PILOTS ATTENTION BETWEEN PITCH AND YAW CHANNELS WERE ALSO EXAMINED.

DOUGHERTY, D., HOUSTON, R.C. AND NICKLAS, D.R. TRANSFER OF TRAINING IN FLIGHT PROCEDURES FROM SELECTED GROUND TRAINING DEVICES TO THE AIRCRAFT. NAVTRADEVEN TR-71-16-16, 1957.

* ABSTRACT *

THIS STUDY WAS DESIGNED TO PROVIDE THE BASIS FOR DECISIONS CONCERNING THE RELATIVE TRAINING EFFECTIVENESS OF A NUMBER OF TRAINING TOOLS FOR THE TASK OF TRAINING PILOTS IN NORMAL AND EMERGENCY PROCEDURES IN NEW AIRCRAFT. IN THIS STUDY A PHOTOGRAPHIC MOCK-UP OF THE COCKPIT, A PARTLY ACTIVATED TRAINER, AN AIRCRAFT FLIGHT SIMULATOR AND THE COMBINATION OF A PART TASK (PROCEDURES TRAINER) AND TIME SHARED TRACKING TASK WERE USED ON EQUIVALENT GROUPS.

1. ALL FOUR METHODS PROVIDED GOOD LEARNING SITUATIONS.
2. THE GROUPS TRAINED ON PROCEDURES TRAINERS AND THE FLIGHT SIMULATOR SHOWED THE HIGHEST DEGREE OF TRANSFER TO THE FIRST AIR TRIAL. NEITHER METHOD WAS SUPERIOR IN THIS RESPECT. IN FACT THESE GROUPS PERFORMED AS WELL AS THE GROUP WHICH PRACTICED IN THE AIRCRAFT FOR FIVE TRIALS.
3. THE PHOTO MOCK-UP PROVIDED THE BEST LEARNING SITUATION AS MEASURED BY PERFORMANCE IN THE GROUND SITUATION.
4. BY THE THIRD AIR TRIAL NO DIFFERENCES COULD BE OBSERVED AS A RESULT OF TRAINING WITH THE DIFFERENT METHODS.
5. THE GROUP THAT LEARNED PROCEDURES WHILE PRACTICING THE TRACKING TASK HAD THE MOST DIFFICULTY LEARNING. TRANSFER TO THE AIRCRAFT WAS NOT QUITE AS HIGH AS PRACTICE IN THE PROCEDURE TRAINER ALONE.
6. IN SUMMARY, NORMAL AND EMERGENCY PROCEDURES CAN BE TAUGHT TRANSITIONING PILOTS IN A VARIETY OF WAYS. FOR PRACTICAL PURPOSES DIFFERENCES IN PERFORMANCE DISAPPEAR AFTER THE FIRST AIR TRIAL.

NAVTRAEQUIPCEN IH-298

DELVILLIER, J.G., JR. AND COATE, R.E. THE COORDINATE-TRANSFORMATION EQUATIONS FOR A PILOTED FLIGHT SIMULATOR WITH SEVERAL DEGREES OF FREEDOM. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D.C., NASA TECHNICAL NOTE D-1150, JANUARY 1962, 24 PP. AD 270 086.

* ABSTRACT *

A METHOD FOR DEVELOPING COORDINATE-TRANSFORMATION EQUATIONS FOR A MULTIPLE-DEGREE-OF-FREEDOM FLIGHT SIMULATOR IS PRESENTED. THE EQUATIONS ARE APPLICABLE IN PARTICULAR TO A FIVE-DEGREE-OF-FREEDOM PILOTED FLIGHT SIMULATOR. IN GENERAL, HOWEVER, THE METHOD OF THEIR DEVELOPMENT IS APPLICABLE TO TRANSFORMATION EQUATIONS FOR OTHER, SIMILAR SIMULATORS OF FEWER OR OF MORE DEGREES OF FREEDOM. BECAUSE THE NASA SIMULATOR HAS A VERY LIMITED RANGE OF DISPLACEMENT IN ONE OF ITS MODES OF MOTION, THE EQUATIONS ARE WRITTEN FOR FOUR DEGREES OF FREEDOM. EXAMINATION OF THE SINGULARITIES OF THE EQUATIONS SHOWED IT POSSIBLE TO REPRODUCE ANY COMBINATION OF FOUR OF THE SIX COMPONENTS OF MOTION, THREE ANGULAR AND THREE LINEAR, OF THE VEHICLE BEING SIMULATED. IN MOST CASES, THERE IS MORE THAN ONE WAY TO SIMULATE EACH COMBINATION, THE MOST DESIRABLE WAY DETERMINED BY THE RESTRICTIONS IMPOSED BY THE SINGULARITIES OF THE EQUATIONS.

DELVILLIER, J.G., TURNER, H.L., MCLEAN, J.D. AND HEINLE, D.R. 'EFFECTS OF FLIGHT SIMULATOR MOTION ON PILOT'S PERFORMANCE OF TRACKING TASKS'. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, NASA TN-D-143, 1960.

* ABSTRACT *

TWO PILOTS FLYING 189 AIR-TO-AIR ATTACKS IN EITHER F86 AIRCRAFT OR SIMULATOR WITH PITCH AND ROLL CUES, OR SAME SIMULATOR STATIC. RESULTS FROM DYNAMIC SIMULATION MORE CLOSELY RESEMBLED THOSE OF FLIGHT THAN DID RESULTS FROM STATIC, ALTHOUGH FLIGHT PERFORMANCE IS GENERALLY LESS PRECISE AND MORE VARIABLE THAN THAT IN DYNAMIC COCKPIT.

CHAND, P.J. A CRITICAL ASSESSMENT OF GROUND-BASED DEVICES FOR SPATIAL ORIENTATION TRAINING. 'SCHOOL OF AEROSPACE MEDICINE', BROOKS AFB, TEXAS, REPORT SAM-TR-73-23, AD-764 740, AUG 1973.

* ABSTRACT *

COMPARISONS ARE MADE OF SELECTED ORIENTATION TRAINING DEVICES IN RELATION TO U.S. AIR FORCE FLIGHT TRAINING IN THE T-38 AIRPLANE. ASSESSMENT CATEGORIES ARE: MOTION PARAMETERS, ILLUSIONS THAT EACH DEVICE CAN GENERATE, TYPE OF INSTRUMENTATION AVAILABLE TO THE PILOT-SUBJECT IN RELATION TO ATTITUDE

REACTION CAPABILITY PROVIDED IN EACH DEVICE FOR THE SUBJECT TO RECOVER OR CORRECT HIS ATTITUDE, CAPABILITY TO MEASURE AND EVALUATE THE SUBJECT'S PERFORMANCE IN COPING WITH DISORIENTING MANEUVERS, INVULNERABILITY TO WEATHER, SAFETY, AND INITIAL AND OPERATING COSTS. THE USAFSAM SPATIAL ORIENTATION TRAINER (SOT) FAR EXCELS ALL OTHER GROUND-BASED DEVICES FOR BOTH THE USE AND NEED OF A SOT-TYPE TRAINER ARE DISCUSSED. (AUTHOR)

DRENNEN, T.G., CURTIN, J.G. AND WARNER, H.D. MANUAL CONTROL IN TARGET TRACKING TASKS AS A FUNCTION OF CONTROL TYPE, TASK LOADING AND VIBRATION. MCDONNELL DOUGLAS AERONAUTICS COMPANY EAST REPORT MDC E1713H, PREPARED FOR ENGINEERING PSYCHOLOGY PROGRAMS, OFFICE OF NAVAL RESEARCH, WASHINGTON, D.C., 1 AUG 1977.

* ABSTRACT *

AN INVESTIGATION WAS CONDUCTED ON THE USE OF FINGERTIP TRACKING CONTROLS WHICH WERE INTEGRATED INTO AN AIRCRAFT THROTTLE GRIP UNDER DIFFERENT LEVELS OF TASK LOADING AND VIBRATION. THE EXPERIMENTAL VARIABLES INCLUDED TWO TYPES OF CONTROL (FORCE AND DISPLACEMENT), TWO LEVELS OF TASK LOADING (LOW AND HIGH) AND FOUR LEVELS OF VIBRATION (STATIC, MODERATE AND HEAVY TURBULENCE AND BROADBAND). THE LOW TASK LOADING CONDITION REQUIRED THE PILOTS ONLY TO TRACK THE DISPLAYED TARGETS OR TO FLY THE SIMULATED AIRCRAFT, WHILE THE HIGH TASK LOADING CONDITION REQUIRED SIMULTANEOUS TARGET TRACKING AND AIRCRAFT ATTITUDE AND AIRSPEED CONTROL. THE VIBRATIONS WERE RANDOM VERTICAL ACCELERATIONS OF 0.11 OR 0.35 GRMS AMPLITUDE ACROSS THE 0.1-20 HZ FREQUENCY RANGE. THE MODERATE TURBULENCE CONDITION WAS 0.11 GRMS IN MAGNITUDE WITH A VIBRATIONAL RESPONSE WHICH PEAKED AT 0.2 HZ. THE HEAVY TURBULENCE CONDITION WAS SIMILAR EXCEPT IT HAD A 0.35 GRMS INTENSITY. THE BROADBAND SPECTRA ALSO HAD A 0.35 GRMS INTENSITY BUT WITH EQUAL RESPONSE ACROSS THE FREQUENCY RANGE. IN THE EVALUATION 16 PILOTS PERFORMED THE TARGET TRACKING AND AIRCRAFT CONTROL TASKS IN A MOTION BASE SIMULATOR. THE DEPENDENT MEASURES WERE PITCH, ROLL AND AIRSPEED ERROR FOR THE AIRCRAFT CONTROL TASKS AND ACQUISITION TIME AND ERROR, OVERSHOTS BEFORE ACQUISITION, PERCENT TIME ON TARGET AND X-Y TRACKING ERROR FOR THE TARGET TRACKING TASKS.

OF THE 10 DEPENDENT VARIABLES, SIGNIFICANT DIFFERENCES BETWEEN THE CONTROL TYPES WERE OBTAINED FOR ONLY TWO MEASURES, TIME-ON-TARGET AND AIRSPEED SCORES. THE FORCE CONTROL PROVIDED SIGNIFICANTLY BETTER TRACKING PERFORMANCE THAN THE DISPLACEMENT CONTROL AS INDICATED BY THE PERCENT TIME-ON-TARGET SCORES. SIGNIFICANTLY LOWER AIRSPEED ERRORS WERE FOUND WHEN TARGET TRACKING WITH THE DISPLACEMENT CONTROL RATHER THAN THE FORCE CONTROL. THE HIGH TASK LOADING CONDITION SIGNIFICANTLY DECREASED PILOT PERFORMANCE IN THE TARGET TRACKING AND AIRCRAFT CONTROL TASKS WHEN COMPARED TO THE LOW TASK LOADING CONDITIONS. THE HIGH AMPLITUDE (0.35 GRMS) VIBRATION CONDITIONS (HEAVY TURBULENCE AND BROADBAND) SIGNIFICANTLY IMPAIRED PILOT

PERFORMANCE, BUT DID NOT INTERACT WITH TASK LOADING OR CONTROL TYPE. HEAVY AND BROADBAND VIBRATION DID NOT SIGNIFICANTLY DIFFER IN THEIR EFFECTS ON PILOT PERFORMANCE. THESE FINDINGS SUGGEST THAT: (1) VERY LOW FREQUENCY VIBRATION (<1.0 HZ) CAN SIGNIFICANTLY AFFECT PERFORMANCE AS A FUNCTION OF INTENSITY LEVEL; (2) DISSIMILAR VIBRATION SPECTRA MAY YIELD SIMILAR EFFECTS DEPENDING UPON VIBRATION INTENSITY AND HUMAN TOLERANCE TO THE SPECTRAL FREQUENCY COMPONENTS; (3) NO CONSISTENT OVERALL PERFORMANCE DIFFERENCES WERE FOUND TO FAVOR EITHER CONTROL TYPE; AND (4) VIBRATION DID NOT INTERACT WITH CONTROL TYPE OR TASK LOADING.

DUNLAP, D.S. AND ANDERSON, F.E. AIR FORCE MASTER PLAN - SIMULATORS FOR AIRCREW TRAINING. AFSC/XPLA, ANDREWS AFB, MD. REPORT NO. ASD/XR 74-22, JUNE 1974.

* ABSTRACT *

THE APPLICATION OF SIMULATORS FOR AIRCREW TRAINING IN THE UNITED STATES AIR FORCE IS ADDRESSED. MAJOR OPERATING COMMANDS PROVIDED CURRENT AND PROJECTED REQUIREMENTS FOR AIRCREW TRAINING SIMULATORS FOR INCORPORATION INTO FORMAL TRAINING PROGRAMS TOGETHER WITH ESTIMATES OF THEIR IMPACT ON FLIGHT TRAINING. A SIMULATOR TECHNOLOGY OVERVIEW IS PROVIDED AND A TECHNOLOGY RESEARCH PROGRAM IS PROPOSED TO SUPPORT FUTURE ACQUISITIONS. ESTIMATES OF PROGRAM COSTS ARE MADE AND THE MAGNITUDE OF POTENTIAL DIRECT OPERATING COSTS AND FUEL SAVINGS ARE PRESENTED FOR EACH OF THE ACQUISITION PROGRAMS. INSTITUTIONAL AND MANAGEMENT PROBLEMS ARE ALSO ADDRESSED.

MOTION SECTION

THE PURPOSE OF A MOTION SYSTEM IS TO IMPART STIMULI OR CUES TO THE TRAINEE WHICH CORRESPOND TO THE CUES WHICH WOULD BE PERCEIVED BY THE HUMAN SENSING MECHANISMS DUE TO THE MOTION OF THE AIRCRAFT. IN ADDITION TO MOTION, OTHER FORCE AND VIBRATION PRODUCING SYSTEMS HAVE BEEN DEVELOPED TO PRODUCE SENSATIONS OF BUFFET AND SUSTAINED G-FORCES. IN GENERAL, THE THRUST OF DEVELOPMENT HAS BEEN AIMED AT DUPLICATING THE FORCES WHICH AN ACTUAL AIRCRAFT IN FLIGHT WOULD IMPART TO THE PILOT. THIS DIRECTION OF DEVELOPMENT HAS PROGRESSED FROM THE TWO DEGREES OF FREEDOM (PITCH AND ROLL) OF THE LINK TRAINER TO THE SIX DEGREE OF FREEDOM SYSTEMS USED TODAY FOR THE MOST MODERN SIMULATORS.

SOFTWARE HAS DEVELOPED ALONGSIDE THE HARDWARE FOR CONTROLLING THE MOTION AND FORCE SYSTEMS. AT LEAST TWO APPROACHES TO COMBINING HARDWARE CAPABILITIES WITH SOFTWARE TO PRODUCE THE DESIRED EFFECTS HAVE DEVELOPED. ONE, AND THE MOST WIDELY USED SOFTWARE APPROACH, UTILIZES FILTERS TO SHAPE ON-SET FORCE CUES AND WASHOUT PROFILES. THE LATTER ARE REQUIRED TO RESTORE THE POSITION OF THE PLATFORM AFTER AN INITIAL DISPLACEMENT TO

PREVENT EXCEEDING THE LIMITS OF TRAVEL OF THE MOTION SYSTEM AND IS ACCOMPLISHED AT A SUBLIMINAL RATE. THIS APPROACH TENDS TO MINIMIZE SOFTWARE COMPLEXITY, BUT LIMITS TO SOME EXTENT UTILIZATION OF THE FULL KINEMATIC CAPABILITY OF THE SYSTEM. THE SECOND APPROACH ATTEMPTS TO DUPLICATE THE ACCELERATION OF THE AIRCRAFT INsofar AS POSSIBLE AND UTILIZES THE FULL KINEMATIC CAPABILITIES OF THE MOTION SYSTEM; WASHOUT PROFILES ARE ANALYTICALLY GENERATED AND, THUS, THE SOFTWARE REQUIREMENTS ARE LARGER BY AN ORDER OF MAGNITUDE FROM THOSE OF THE FORMER METHOD. THE ASUPT PROGRAM WILL UTILIZE THE MORE SOPHISTICATED TECHNIQUE TO INVESTIGATE THE RELATIVE MERITS OF IT VERSUS THE LESS COMPLEX APPROACH TO MOTION SOFTWARE.

WHILE THE MOTION SYSTEM ITSELF IS CAPABLE OF PROVIDING FORCE ON-SET CUES, SUSTAINED FORCE CUES ARE PROVIDED BY G-SEATS, G-SLITS, SEAT BELTS, ETC., TO PROVIDE PRESSURES ON THE BODY SIMILAR TO THOSE EXPERIENCED IN THE AIR. RESEARCH EFFORTS HAVE BEEN CONDUCTED BY THE AFHRL TO EXAMINE MATHEMATICALLY THE HUMAN FORCE AND MOTION SENSING MECHANISMS, PARTICULARLY THOSE ASSOCIATED WITH THE INNER EAR, MUSCULAR SUPPORT FOR THE HEAD AND BODY EXTREMITIES AND BODY PRESSURES. THIS RESEARCH TENDS TO SHOW THE INNER EAR IS A LESS RELIABLE SENSING MECHANISM THAN THE MUSCULAR SUPPORT AND BODY PRESSURE SENSING MECHANISMS. WHILE LESS RELIABLE THE INNER EAR RESPONSES TO MOTION ARE IMPORTANT IN THAT THE ABSENCE OF THESE CUES IN THE PRESENCE OF OTHER MOTION CUES, SUCH AS THOSE PERCEIVED BY THE EYE FROM A VISUAL DISPLAY, CAN PRODUCE NAUSEA IN THE EXPERIENCED PILOT CONDITIONED TO COMBINATIONS OF SENSORY STIMULI. THEIR ABSENCE IN A SIMULATOR COULD ALSO LEAD TO DISORIENTATION IN THE REAL AIR SITUATION FOR A UPT STUDENT CONDITIONED BY LESS COMPLETE COMBINATIONS OF MOTION CUES. ADDITIONAL RESEARCH IS NECESSARY TO CONFIRM THE ANALYTICAL RESULTS TO HELP GUIDE FUTURE SIMULATOR DEVELOPMENT. UPON COMPLETION OF THE DEVELOPMENT AND TEST OF THE ASUPT WHICH ENCOMPASSES MOTION AND FORCE SIMULATION THROUGH A COMBINATION OF A SIX DEGREE OF FREEDOM SYNERGISTIC (6-DOF) MOTION SYSTEM AND A G-SEAT, THE MOTION AND FORCE RESEARCH WILL BE CONTINUED. TO DATE, VERY LITTLE RESEARCH HAS BEEN DEVOTED TO ALTERNATIVE METHODS OF INDUCING MOTION CUES OTHER THAN THE DUPLICATIVE APPROACH DESCRIBED ABOVE. RESEARCH IS NECESSARY TO BETTER UNDERSTAND THE HUMAN IN TERMS OF HOW HE SENSES FORCE AND MOTION AND TO DEVELOP, IF POSSIBLE, ARTIFICIAL MEANS FOR STIMULATING THESE SENSING MECHANISMS. EQUALLY IMPORTANT IS THE STUDY OF THE SYNERGISTIC EFFECTS OF COMBINING FORCE AND MOTION CUES WITH VISUAL SYSTEMS. THE CROSS COUPLING OF SIGHT SENSING AND MOTION SENSING IS NOT WELL UNDERSTOOD AND IS CRUCIAL TO THE DETERMINATION OF WHERE AND WHEN AND HOW MUCH MOTION AND FORCE PRODUCING APPARATUS IS NECESSARY TO MEET SPECIFIC TRAINING NEEDS.

THE AEROSPACE MEDICAL RESEARCH LABORATORY (AMRL) IS UNIQUELY QUALIFIED TO INVESTIGATE THE PHYSIOLOGICAL PHENOMENA ASSOCIATED WITH CONFLICTING SENSORY CUES. RESEARCH IS PROPOSED TO QUANTIFY THE EFFECTS OF MOTION AND CONFLICTING VISUAL CUES TO DETERMINE THE BOUNDARIES IMPOSED BY LIMITED MOTION SYSTEMS TO

CREATE THE ILLUSION OF FLIGHT WITH REAL DISORIENTATION AS
OPPOSED TO UNDESIRABLE DISORIENTATION.

DUNLAP, D.S. AND WORTHLEY, R.E.
AIR FORCE MASTER PLAN SIMULATORS FOR AIRCREW TRAINING, ASD/XR
TR 75-25 ANDREWS AFB, MARYLAND, SEPTEMBER 1975

* ABSTRACT *

THE APPLICATION OF SIMULATORS FOR AIRCREW TRAINING IN THE UNITED STATES AIR FORCE IS ADDRESSED. MAJOR OPERATING COMMANDS PROVIDED CURRENT AND PROJECTED REQUIREMENTS FOR AIRCREW TRAINING SIMULATORS FOR INCORPORATION INTO FORMAL TRAINING PROGRAMS TOGETHER WITH ESTIMATES OF THEIR IMPACT ON FLIGHT TRAINING. A SIMULATOR TECHNOLOGY OVERVIEW IS PROVIDED AND A TECHNOLOGY RESEARCH PROGRAM IS PROPOSED TO SUPPORT FUTURE ACQUISITIONS. ESTIMATES OF PROGRAM COSTS ARE MADE AND THE MAGNITUDE OF POTENTIAL DIRECT OPERATING COSTS AND FUEL SAVINGS ARE PRESENTED FOR EACH OF THE ACQUISITION PROGRAMS. INSTITUTIONAL AND MANAGEMENT PROBLEMS ARE ALSO ADDRESSED.

CLUSTERBERRY, J.C. AND BARNETT, R.M. A MULTIPURPOSE RESEARCH LABORATORY FOR FLIGHT SIMULATION. (THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, ASME PAPER 63-AHGT-87, JAN 1963.

* ABSTRACT *

WHILE THE OPERATIONAL FLIGHT TRAINER OR PROCEDURES TRAINER CAN BE DESIGNED ABOUT A SPECIFIC MISSION OR VEHICLE, A RESEARCH LABORATORY MUST PROVIDE FLEXIBILITY TO ALLOW SIMULATION OF A VARIETY OF FLIGHT SITUATIONS. THE EXISTING SIMULATION FACILITIES OF THE AMES RESEARCH CENTER ARE BRIEFLY DESCRIBED AND INCLUDE THE FIVE-DEGREE-OF-FREEDOM FLIGHT SIMULATOR, THE TRANSPORT LANDING SIMULATOR, HEIGHT CONTROL APPARATUS, AIR-BEARING-SUPPORTED SIMULATORS, AND THEIR INTEGRATION WITH THE GENERAL PURPOSE ELECTRONIC ANALOG COMPUTERS. AS A SPECIFIC EXAMPLE OF THE FLEXIBILITY AVAILABLE IN THE APPARATUS, THE APPLICATION OF THE FIVE-DEGREE-OF-FREEDOM FLIGHT SIMULATOR TO BOTH A TRANSPORT HANDLING PROBLEM AND A SPACE VEHICLE REENTRY PROBLEM IS DESCRIBED. METHODS OF INTERCONNECTION OF COMPUTERS, SIMULATORS, AND INSTRUMENT DISPLAYS ARE DISCUSSED. (AUTHOR)

DYDA, K.C. AND MCLEAN, W.N. THE USE OF FLIGHT SIMULATORS TO INVESTIGATE SUPERSONIC TRANSPORT LANDING IMPACT CRITERIA. NORTH AMERICAN AVIATION, INC., LOS ANGELES, CA, SUPERSONIC TRANSPORT RESEARCH PROGRAM SPONSORED BY THE FEDERAL AVIATION AGENCY, REPORT NA-63-253-1, MAR 1963.

* ABSTRACT *

AN ADVANCED SIMULATOR WHICH CAN BE USED TO SIMULATE LANDINGS IN A CURRENT JET TRANSPORT, IS DESCRIBED. A COMBINATION OF HYBRID COMPUTATION, MOVING COCKPIT, AND UNIQUE DISPLAY SYSTEM REDUCE CERTAIN SHORTCOMINGS CHARACTERISTIC OF OTHER CURRENT LANDING SIMULATOR SYSTEMS. THE VARIOUS CONSIDERATIONS WHICH AFFECT A SIMULATION OF THIS NATURE ARE DISCUSSED.

THE VALIDITY OF THE SIMULATION IS TO BE ESTABLISHED BY USING AIRLINE PILOTS TO FLY CURRENT SUBSONIC TRANSPORT LANDINGS AND MEASURE LANDING SPEEDS AND SINK RATES. THESE WILL BE COMPARED WITH ACTUAL FLIGHT STATISTICS. ONCE THIS VALIDITY IS ESTABLISHED, A SIMPLE CHANGE IN COMPUTER INPUT DATA CAN CONVERT THE SIMULATION INTO ONE REPRESENTING SUPERSONIC TRANSPORT CHARACTERISTICS. USING THIS SIMULATION, LANDING IMPACT CRITERIA FOR VARIOUS CONFIGURATIONS OF SUPERSONIC TRANSPORTS CAN BE PREDICTED.

THIS EFFORT IS SPONSORED BY THE FEDERAL AVIATION AGENCY WITH THE TECHNICAL SUPPORT OF DEPARTMENT OF DEFENSE, AERONAUTICAL SYSTEMS DIVISION, AND NATIONAL AERONAUTICS AND SPACE ADMINISTRATION. (AUTHOR)

EDENBOROUGH, R. A.
RAF INSTITUTE OF AVIATION MEDICINE,
FARNBOROUGH, HANTS,
IAM REPORT 433, MAR 1968.
USER OPINION OF RAF FLIGHT SIMULATORS

* ABSTRACT *

AS PART OF THE RESEARCH OF FLIGHT SIMULATION REQUIREMENTS AN OPEN-ENDED QUESTIONNAIRE WAS ADMINISTERED TO USERS OF RAF FLIGHT SIMULATORS. QUESTIONS ABOUT MOTION REQUIREMENTS, VISUAL WORLD REQUIREMENTS AND ACCEPTABILITY WERE EXAMINED. NO DIFFERENCES WERE FOUND BETWEEN DIFFERENT GROUPS WITH REGARD TO THE FIRST TWO OF THESE, BUT UNITS USING FIXED-BASE SIMULATORS REPRESENTING TRANSPORT AIRCRAFT FOUND THESE DEVICES SIGNIFICANTLY LESS ACCEPTABLE THAN GROUPS USING OTHER SIMULATORS.

IT IS SUGGESTED THAT THE COMMENTS APPEARING MOST FREQUENTLY IN THIS STUDY MAY BE USED:

1. TO PRODUCE QUESTIONNAIRES CAPABLE OF MORE SOPHISTICATED QUANTITATIVE ANALYSIS.
2. AS DIRECT INDICATIONS OF THE MOTION AND VISUAL CUES THE USERS FEEL WOULD BE MOST USEFULLY INCULDED IN FUTURE SIMULATORS

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EDWARDS, A. - DEVICE FOR INSTRUCTING STUDENTS IN FLYING
PATENT NO. 2,306,429
FILED DEC. 23, 1941 GRANTED DEC. 29, 1942

ABSTRACT

ELDRIDGE, W. M. AND CRANE, H. L.
USE OF A LARGE JET TRANSPORT AS AN INFLIGHT DYNAMIC SIMULATOR.
NORTH ATLANTIC TREATY ORGANIZATION,
ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT
AGARD REPORT 528, MAY 1966.

* ABSTRACT *

THE SUPERSONIC TRANSPORT CONFIGURATIONS NOW BEING STUDIED ARE CONSIDERABLY DIFFERENT FROM THE EXISTING SUBSONIC JET TRANSPORTS AND IT IS EXPECTED THAT THE FLIGHT CHARACTERISTICS DURING THE CRITICAL LOW-SPEED APPROACH AND LANDING WILL POSE PROBLEMS. IN ORDER TO OBTAIN INFORMATION ON THESE LOW-SPEED FLIGHT CHARACTERISTICS, THE NASA-LANGLEY RESEARCH CENTER CONTRACTED WITH THE BOEING COMPANY TO MODIFY THE ORIGINAL BOEING 707 PROTOTYPE (THE MODEL 367-80 AIRPLANE) FOR USE AS AN INFLIGHT SIMULATOR.

THIS PAPER WILL DISCUSS THE INFLIGHT SIMULATION SYSTEM THAT WAS DEVELOPED FOR THESE TESTS. INCLUDED IN THE PAPER WILL BE DISCUSSIONS OF THE UNIQUE USE OF SPOILERS AND THRUST REVERSERS TO SIMULATE VARIATIONS IN LIFT AND DRAG WITH ANGLE OF ATTACK, THE ABILITY TO VARY THE LONGITUDINAL CHARACTERISTICS TO SIMULATE THE GROUND PROXIMITY, AND THE GROUND-BASED SIMULATOR AND COMPUTER STUDIES USED TO INVESTIGATE PROBLEM AREAS AND CHECK THE QUALITY OF SIMULATION.

THIS PAPER WAS PRESENTED AT THE TWENTY-EIGHTH MEETING OF THE AGARD FLIGHT MECHANICS PANEL, HELD IN PARIS, FRANCE, ON 10-11 MAY 1966.

ELLIS, A. C., LOWES, A., MATHENY, W. G., AND NORMAN, D.
PILOT PERFORMANCE TRANSFER OF TRAINING AND DEGREE OF SIMULATION
III. PERFORMANCE OF NON-JET EXPERIENCED PILOTS VERSUS
SIMULATION FIDELITY.
NAVTRADEVEN 67-C-0034-1.
U. S. NAVAL TRAINING DEVICE CENTER, ORLANDO, FLORIDA,
AUGUST 1968.

* ABSTRACT *

THIS IS THE FOURTH REPORT IN A STUDY PROGRAM DEALING WITH PILOT PERFORMANCE, TRANSFER OF TRAINING AND DEGREE OF SIMULATION.

THE PURPOSE OF THIS STUDY WAS TO REPEAT A PREVIOUSLY CONDUCTED TRANSFER OF TRAINING STUDY USING NON-JET EXPERIENCED PILOTS AS SUBJECTS. ITS PRIMARY OBJECTIVE WAS TO DETERMINE THE TRAINING FEASIBILITY OF USING DEGRADED LEVELS OF SIMULATION FIDELITY IN AN OPERATIONAL FLIGHT TRAINER (OFT). SIMULATION FIDELITY WAS VARIED BY INCORPORATING COEFFICIENT CHANGES INTO THE AERODYNAMIC EQUATIONS OF FLIGHT SUCH THAT RIGID COEFFICIENTS AND LEAST SQUARES APPROXIMATIONS TO FLEXIBLE COEFFICIENTS SERVED AS THE EXPERIMENTAL CONDITIONS AND FLEXIBLE COEFFICIENTS, SERVED AS THE CONTROL CONDITION. ON THE BASIS OF STUDY RESULTS, IT WAS CONCLUDED THAT THE FEASIBILITY OF RIGID COEFFICIENTS FOR OFT TRAINING HAD BEEN DEMONSTRATED; HOWEVER, THE TRAINING UTILITY OF THE LEAST SQUARES APPROXIMATIONS WAS DOUBTFUL. IT IS RECOMMENDED THAT FURTHER STUDY SHOULD BE UNDERTAKEN USING OTHER FLIGHT REGIMES AND TRAINING MANEUVERS.

ELLIS, N. C., LOWES, A. L., MATHENY, W. G., NORMAN, D. A. AND WILKERSON, L. E.
PILOT PERFORMANCE, TRANSFER OF TRAINING AND DEGREE OF SIMULATION: II. VARIATIONS IN AERODYNAMIC COEFFICIENTS.
NAVAL TRAINING DEVICE CENTER
TECH. REPT. NAVTRADEVCEEN 1889-1, MAY 1967.

* ABSTRACT *

THIS IS THE THIRD REPORT IN A STUDY PROGRAM DEALING WITH PILOT PERFORMANCE, TRANSFER OF TRAINING AND DEGREE OF SIMULATION. TRANSFER OF TRAINING STUDIES WERE CONDUCTED TO DETERMINE THE TRAINING FEASIBILITY OF SIMULATORS REDUCED BY VARYING AERODYNAMIC COEFFICIENTS. EXPERIMENT ONE INCORPORATED THE COEFFICIENT CHANGES IN THE LONGITUDINAL MODE; EXPERIMENT TWO IN THE LATERAL MODE; AND EXPERIMENT THREE IN THE COMBINED LONGITUDINAL AND LATERAL MODES. FROM THE STUDY RESULTS, IT WAS CONCLUDED THAT FEASIBILITY OF THESE REDUCED SIMULATIONS AS CONDITIONS FOR TRAINING HAD BEEN DEMONSTRATED. FURTHER STUDY USING OTHER PILOT POPULATIONS, FLIGHT REGIMES, MANEUVERS AND SIMULATOR CAPABILITIES TO DETERMINE FULL IMPLICATIONS OF THESE FINDINGS SHOULD BE UNDERTAKEN. (AUTHORS)

EMERY, J.G., SONNEBORN, W.G., AND ELAM, C.B. A STUDY OF THE VALIDITY OF GROUND-BASED SIMULATION TECHNIQUES FOR THE UH-1B HELICOPTER. BELL HELICOPTER CO., FORT WORTH, TX FOR USAAVLABS, REPT. 1 TR-67-72, AD-667 988, DEC 1967.

* ABSTRACT *

THE WORK EXPLORED THE CHARACTERISTICS OF SOME SIMULATOR AND FLIGHT DATA WHICH WERE COLLECTED IN A UH-1B HELICOPTER AND A

GROUND-BASED SIMULATED VERSION OF THE SAME. ANALYTICAL TREATMENTS ARE DESCRIBED AND APPLIED TO THESE DATA. THEY ARE AUTOCORRELATION AND CROSS CORRELATION FUNCTIONS, PILOT ERROR AND PILOT EFFICIENCY. RESULTS ARE REPORTED ON THE EFFECTIVENESS OF CERTAIN SIMULATOR VARIABLES AND PERFORMANCE MEASUREMENT TECHNIQUES. (AUTHOR)

ENER, E.L., JR. A STUDY OF PILOT PERFORMANCE DURING A GLIDE-SLOPE APPROACH WHEN RATE INFORMATION IS SUPPLIED VIA THE PERIPHERAL VISION. 'AIR FORCE INSTITUTE OF TECHNOLOGY' REPORT GE/MA/74D-2, WRIGHT-PATTERSON AFB, OH, DEC 1974.

* ABSTRACT *

A PRESENTATION IS MADE OF THE FINDINGS OF A FIXED-BASE SIMULATION STUDY DURING WHICH THE RATE OF GLIDE-SLOPE DEVIATION WAS PROVIDED VIA THE PERIPHERAL VISION TO THE PILOT, WHILE FLYING A SIMULATED GLIDE-SLOPE APPROACH. THE METHOD USED TO SUPPLY GLIDE-SLOPE DEVIATION WAS BY THE MOVEMENT OF ALTERNATING BLACK AND WHITE LINES DISPLAYED IN THE PERIPHERAL VISION. PILOT PERFORMANCE WAS MEASURED DURING GLIDE-SLOPE RUNS PERFORMED WITHOUT THE PERIPHERAL DISPLAY AND A COMPARISON MADE WITH PERFORMANCE MEASURED DURING USE OF THE DISPLAY. FINDINGS SHOW THAT A PERIPHERAL DISPLAY WHICH PRESENTS RATE INFORMATION CAN BE USED TO IMPROVE PERFORMANCE FOR MOST PEOPLE.

A PRESENTATION IS ALSO MADE OF THE FINDINGS OF A SIMULATION INVOLVING A SECOND-ORDER CRITICAL TASK. FINDINGS FROM THIS SIMULATION SHOW THAT THE SECOND-ORDER CRITICAL TASK CAN BE SUCCESSFULLY USED TO DETERMINE IF AN INDIVIDUAL IS CAPABLE OF IMPROVING PERFORMANCE BY THE USE OF A PERIPHERAL DISPLAY WHICH PRESENTS RATE INFORMATION.

FNEY, J.A. MOVING-BASE SIMULATION OF THE F-14 STALL/SPIN. NAVAL AIR DEVELOPMENT CENTER, WARMINSTER, PA. NADC-73085-30 73/06/06

* ABSTRACT *

A THREE-DEGREE OF FREEDOM CENTRIFUGE WAS USED TO PROVIDE A MOVING-BASE PILOT CONTROLLED SIMULATION OF THE F-14 AIRPLANE IN THE STALL-SPIN FLIGHT REGIME. VARIOUS PILOTING TECHNIQUES WERE EVALUATED IN ENTERING, RECOVERING FROM, AND FORESTALLING UNCONTROLLED POST-STALL GYRATIONS AND FULLY DEVELOPED SPINS. PROPOSED SYSTEMS WHICH AUTOMATICALLY FORESTALL DEPARTURE WERE APPROXIMATED AND EVALUATED. AVOIDING THE YAW DUE TO DIFFERENTIAL TAIL DEFLECTION WAS FOUND TO BE THE PREDOMINANT FACTOR IN MAINTAINING CONTROL AT THE STALL.

FAYE, A.E. ATTITUDE CONTROL REQUIREMENTS THROUGH THE USE OF A PILOTED FLIGHT SIMULATOR. NASA-TN-D-792, APRIL 1961.

* ABSTRACT *

A PILOTED SIMULATOR INVESTIGATION HAS BEEN CONDUCTED TO ESTABLISH ATTITUDE CONTROL REQUIREMENTS FOR HOVERING FLIGHT. REALISTIC CONTROLLABILITY BOUNDARIES OF CONTROL POWER AND DAMPING VALUES WERE ESTABLISHED ABOUT EACH OF THE THREE AXES, ONE AT A TIME, UNDER IDEAL CONDITIONS. THESE SINGLE-AXIS BOUNDARIES SHIFTED AND BECAME MORE RESTRICTIVE WHEN SIMULTANEOUS CONTROL ABOUT TWO AXES WAS PRESENTED THE PILOT, WITH THE CONTROLS HARMONIZED. FURTHER SHIFTING OF THE BOUNDARIES WAS INDICATED WHEN THE CONTROLS WERE NOT HARMONIZED, OR WHEN GYROSCOPIC COUPLING WAS ADDED.

GYROSCOPIC COUPLING BETWEEN THE PITCH AND YAW FREEDOM OF MOTION RESULTED IN A RAPID DETERIORATION OF CONTROLLABILITY WITH INCREASING AMOUNTS OF GYROSCOPIC COUPLING, ESPECIALLY WHEN THE DAMPING WAS REDUCED TO LOW VALUES.

A COMPARISON OF SIMULATOR CONTROLLABILITY RESULTS WITH FLIGHT INDICATES GOOD CORRELATION BETWEEN THE SIMULATOR TWO-AXES RESULTS AND THE VTOL AIRPLANE ALL-AXES RESULTS.

FEDDERSON, W.E. 'SIMULATOR RESEARCH: VALIDATION AND MOTION STUDIES'. IN SEVENTH ANNUAL ARMY HUMAN FACTORS ENGINEERING CONFERENCE, OCTOBER, 1961. AD 267 153

* ABSTRACT *

THE PURPOSE OF THE STUDY WAS TO DEMONSTRATE WITH EXPERIMENTAL DATA THE EXTENT TO WHICH PERFORMANCE RESULTS ON THE SIMULATOR APPROXIMATE THOSE OBTAINED FROM THE HELICOPTER WHEN THE TASKS ARE EQUIVALENT.

THE APPROACH WAS THREE-FRONGED.

1. LOOKED AT THE EFFECT OF VARIOUS TYPES OF MOTION UPON OPERATOR PERFORMANCE.
2. LOOKED AT THE CONTRIBUTION OF MOTION CUES RELATIVE TO NO MOTION IN THE SIMULATOR TRACKING SITUATION.
3. INVESTIGATION OF THE VARIOUS MEASURES WHICH CAN BE USED IN THE EVALUATION OF OPERATOR PERFORMANCE AND SYSTEM PERFORMANCE.

RESULTS SHOWED THAT WHEN THE TASK WAS TO HOLD A HOVER (HOLD THEIR POSITION RELATIVE TO INFORMATION PRESENTED IN THE DISPLAY) THE MOTION GROUP LEARNED MORE QUICKLY. HOWEVER, WHEN TRANSFER WAS MADE, THE MOTION GROUP PERFORMANCE DETERIORATED AND THE NO-MOTION GROUP IMPROVED SO THAT THEIR RELATIVE POSITION WAS REVERSED.

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THE IMPORTANT THING HERE IS THAT THE MOTION GROUP AFTER BEING SWITCHED TO THE NO-MOTION CONDITION, NEVER GETS BACK TO THE LEVEL WHICH HAD BEEN PREVIOUSLY OBTAINED. THIS INDICATED THAT THE INFORMATION WHICH CONTRIBUTED TO PROFICIENCY IN THE ORIGINAL TRAINING SITUATION IS NO LONGER PRESENT. IN TRANSFERRING TO THE ACTUAL HELICOPTER THERE WERE NO SIGNIFICANT DIFFERENCES IN TRIALS TO ASYMPTOTIC PERFORMANCE.

FEDDERSON, W.E. 'THE ROLE OF MOTION INFORMATION AND ITS CONTRIBUTION TO SIMULATION VALIDITY'. BELL HELICOPTER CO., REPORT NO. D-228-429-001, APRIL 1962.

* ABSTRACT *

THE USE OF A MOTION SIMULATOR IN THE EVALUATION AND TESTING OF DISPLAY AND INSTRUMENTATION CONCEPTS WHICH ARE CENTRAL TO THE OBJECTIVES OF THE ARMY-NAVY INSTRUMENTATION PROGRAM (ANIP) POSES THE SAME QUESTION, TO WHAT EXTENT DOES THE DEVICE ALLOW A VALID EVALUATION OF THE DEVELOPMENTS UNDER CONSIDERATION. THE ULTIMATE IN VALIDITY WOULD BE ACHIEVED WHEN OPERATOR BEHAVIOR IN THE SIMULATOR CORRESPONDS PRECISELY TO CONTROL BEHAVIOR IN THE SYSTEM BEING SIMULATED WHICH, IN THIS CASE, IS A HELICOPTER IN ALL OF ITS FLIGHT MODES. SINCE IT IS UNREALISTIC TO EXPECT EXACT BEHAVIOR CORRESPONDENCE IN THE TWO SITUATIONS, THE TASK IS ONE OF DETERMINING THE EXTENT OR DEGREE OF APPROXIMATION. THIS REPORT SUMMARIZES THE RESULTS OF A SERIES OF THREE INVESTIGATIONS, BOTH SIMULATOR AND FLIGHT TEST, DESIGNED TO DETERMINE THE RELATIVE PROFICIENCY ALLOWED BY MOTION INFORMATION IN THE SIMULATOR IN A HOVERING FLIGHT MODE AND SECONDLY, TO DETERMINE WITH APPROPRIATE MEASURES THE DEGREE TO WHICH CONTROL BEHAVIOR IN THE HELICOPTER IS APPROXIMATED BY BEHAVIOR IN THE SIMULATOR WHEN THE TASKS ARE EQUIVALENT. THE PROFICIENCY RESULTS ARE REPORTED IN TERMS OF INTEGRATED ABSOLUTE ERROR SCORES ABOUT THE VARIOUS AXES DEFINING THE HOVERING TASK, AND THE BEHAVIORAL DATA, ARE PRESENTED IN THE FORM OF AUTO-CORRELATION FUNCTIONS.

THE OPERATOR'S PROPRIOCEPTIVE SENSES ARE SENSITIVE TO ONSET. IF THE OPERATOR CAN SENSE THIS THIRD DERIVATIVE... AND INITIATE EVEN AN APPROXIMATE CORRECTIVE RESPONSE, HE IS CONSIDERABLY AHEAD OF THE VISUAL SENSE ALONE IN CONTROLLING THE SYSTEM... PERCEPTION OF THESE DERIVATIVES OPERATES IN EFFECT TO QUICKEN THE DISPLAY COMPLEX... SUBJECTS' RESPONSE UNDER THE MOTION CONDITION IS CHARACTERIZED BY... SHORTER RESPONSE TIME TO AN ERROR.

FESSENDEN, EMMA I., HALL, R.A., AND CROSBIE, R.K. DYNAMIC SIMULATION OF SPIN ON THE HUMAN CENTRIFUGE, REPORT OF PHASE I, 'NAVAL AIR DEVELOPMENT CENTER REPORT' NADC-MR-6813, 16 SEPT 1968

* ABSTRACT *

THE SPIN MANEUVERS OF A NAVY F4B FIGHTER AIRCRAFT HAS BEEN DYNAMICALLY SIMULATED ON THE HUMAN CENTRIFUGE AT THE AEROSPACE MEDICAL RESEARCH DEPARTMENT (AMRD) OF THE NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA. AN ACTUAL F4B COCKPIT WAS MOUNTED AND INSTRUMENTED IN THE CENTRIFUGE GONDOLA AND DATA FROM ACTUAL SPIN FLIGHT TESTS WERE UTILIZED AS EVALUATORS AND JUDGED THE REALISM OF THE OPEN LOOP SPIN SIMULATION. THIS REPORT CONCERNS THE REACTIONS OF THESE PILOTS. AN ATTEMPT IS MADE TO ASSESS THE INFLUENCE OF THE PILOT'S BACKGROUND, I.E., BOTH TRAINING AND EDUCATION, ON HIS REACTION TO THE DYNAMIC SIMULATION. THE VALUE OF THE STATIC VERSUS THE DYNAMIC SIMULATION IS DISCUSSED. A VISUAL DISPLAY CONSISTING OF AN OUT-THE-WINDOW VIEW OF THE SPIN WAS PRESENTED TO THE PILOT DURING THE LATER PART OF THE PROGRAM. THIS OPEN LOOP SIMULATION HAS SUBSTANTIATED THE CONCEPT OF USING THE CENTRIFUGE AS A DYNAMIC SIMULATOR FOR AIRCRAFT SPIN MANEUVERS. (AUTHOR)

FITZPATRICK, R. 'TOWARD A THEORY OF SIMULATION'. PAPER PRESENTED AT THE ANNUAL MEETING OF THE HUMAN FACTORS SOCIETY, NEW YORK CITY, NOVEMBER 1962.

* ABSTRACT *

THE CONCEPT OF SIMULATION, THOUGH INTUITIVELY EASY TO GRASP, HAS NOT BEEN PRECISELY DEFINED NOR HAVE PRINCIPLES UPON WHICH TO BASE SIMULATION DECISIONS BEEN ESTABLISHED. DISCUSSIONS OF THE SUBJECT USE DIVERSE VOCABULARIES SO THAT AN INTEGRATED CONCEPT OF SIMULATION IS HARD TO COME BY. IT IS THE PURPOSE OF THIS PAPER TO ATTEMPT A STANDARDIZATION OF VOCABULARY AND INTEGRATION OF IDEAS WITH A VIEW TO ESTABLISHING A BASE UPON WHICH A THEORY OF SIMULATION MAY BE BUILT. (AUTHOR)

FLEISHMAN, E.A. AND RICH, S. 'ROLE OF KINESTHETIC AND SPATIAL-VISUAL ABILITIES IN PERCEPTUAL-MOTOR LEARNING'. JOURNAL OF EXPERIMENTAL PSYCHOLOGY, V66, NO. 1 JULY 1963.

* ABSTRACT *

SJS WERE ADMINISTERED A SPATIAL TEST AND A NEW MEASURE OF 'KINESTHETIC SENSITIVITY,' AND THEN RECEIVED EXTENDED PRACTICE ON A TWO-HAND COORDINATION (THC) TASK. THE RESULTS CONFIRM THE HYPOTHESIS THAT SENSITIVITY TO PROPRIOCEPTIVE CUES ARE MORE IMPORTANT LATER IN PERCEPTUAL-MOTOR LEARNING WHILE SENSITIVITY TO EXTEROCEPTIVE (SPATIAL-VISUAL) ARE MORE CRITICAL EARLIER IN LEARNING. THE STUDY EXTENDS PREVIOUS WORK WHICH SHOWED THAT ABILITIES WHICH CONTRIBUTE TO LEARNING EARLY IN PRACTICE MAY BE DIFFERENT FROM THOSE WHICH FACILITATE LATER LEARNING. (AUTHOR)

FLETCHER, D.E., COLLINS, C.C. AND BROWN, J.L. EFFECTS OF POSITIVE ACCELERATION UPON THE PERFORMANCE OF AN AIR-TO-AIR TRACKING TASK. JOURNAL OF AVIATION MEDICINE, VOLUME 29, PP. 891-897, DECEMBER 1958.

* ABSTRACT *

IN A SIMULATED AIR-TO-AIR COMPENSATORY TRACKING TASK ON THE CENTRIFUGE, EACH OF FOUR SUBJECTS PARTICIPATED IN SEVENTY-TWO RUNS. IN EACH 141 SECOND RUN, A LIGHT AT THE NINETY-FIRST SECOND SIGNALLED THE SUBJECT TO PRESS A CONTROL STICK BUTTON AFTER CHECKING THAT THE TARGET AIRCRAFT WAS CENTERED ON THE OSCILLOSCOPE. ACCORDING TO ANALYSIS OF VARIANCE THIS TIME SCORE WAS UNAFFECTED BY CHANGES IN CONTROL STICK OR IN DURATION LEVEL, AND LOCATION OF ACCELERATION; BUT IT DID VARY SIGNIFICANTLY FOR DIFFERENT SUBJECTS. FOR TRACKING ERROR SCORES, TAKEN AS THE VERTICAL AND THE HORIZONTAL CUMULATED ABSOLUTE DEVIATION OF THE TARGET FROM THE CENTER OF THE SCOPE, ALL MAIN VARIABLES AND MANY INTERACTIONS WERE SIGNIFICANT BY ANALYSIS OF VARIANCE. TRACKING WAS MORE ACCURATE WITH THE RIGHT-HAND CONTROL STICK THAN WITH THE CENTER STICK, WITH TEN SECONDS OF ACCELERATION AS COMPARED TO THIRTY SECONDS OF ACCELERATIONS, WITH 1 AS COMPARED TO 2 OR 3G OR WITH 1 OR 2 AS COMPARED TO 3 OR 4G OF ACCELERATION. ACCURACY WAS NOT AFFECTED BY THE LOCATION OF THE ACCELERATION WITHIN A RUN. DIFFERENT SUBJECTS VARIED CONSIDERABLY IN TRACKING ACCURACY. THE SIGNIFICANT INTERACTIONS BETWEEN VARIABLES APPEARED TO BE UNSYSTEMATIC.

R. FLEXMAN AND W. POWE - PATENT DISCLOSURE ON G SEAT. LINK GROUP, GENERAL PRECISION SYSTEMS, INC., BINGHAMTON, N.Y., 1965.

NO ABSTRACT

FLEXMAN, R.E.
MAN IN MOTION 'THE CONNECTING LINK'
GENERAL PRECISION, INC. BINGHAMTON, N.Y. 3 12-18, 1966

* ABSTRACT *

THIS ARTICLE MAKES A CASE FOR THE IMPORTANCE OF PROPRIOCEPTIVE CUES IN FLIGHT AND THE ADVANTAGES OF PROVIDING SIMILAR CUES IN THE FLIGHT SIMULATOR SITUATION. ANALYSES SHOW THAT THE PORTION OF THE TOTAL CUE SPECTRUM OF FLIGHT THAT IS RECEIVED BY THE PROPRIOCEPTIVE SENSORS IS INTEGRAL AND IMPORTANT TO THE DEVELOPMENT OF AN ADEQUATE REPERTOIRE OF RESPONSES. BECAUSE REACTION TIME TO KINESTHETIC STIMULI IS SIGNIFICANTLY SHORTER THAN TO VISUAL STIMULI, THE PROPRIOCEPTORS ENABLE A PILOT TO QUICKEN HIS ENTIRE FLIGHT RESPONSE NETWORK AND TO KEEP HIS

THOUGHT PROCESSES AHEAD OF THE AIRCRAFT. VALID ARGUMENTS AGAINST THE PHILOSOPHY OF IGNORING PHYSICAL CUES IN FLIGHT ARE PRESENTED.

A REVIEW OF THE LITERATURE AND RESULTS FROM A NUMBER OF IN-HOUSE STUDIES SUGGEST THAT THE MOTIONS WHICH SHOULD BE SIMULATED ARE THOSE THAT DEPICT THE DIRECTION AND RATE OF ONSET OF ACCELERATIONS, CHARACTERISTIC VIBRATIONS, HEAVY TURBULENCE, CRITICAL BUFFET CUES AND THE CORRELATED DISBURBANCES ASSOCIATED WITH SPECIFIC MALFUNCTIONS. FADEOUT OF ACCELERATION CUES MUST BE ACCOMPLISHED AT BELOW THRESHOLD RATES TO COMPENSATE FOR LIMITS INFERENT IN FLIGHT SIMULATORS AND SOME CUEING OF THE SUSTAINED ACCELERATION IS DEEMED DESIRABLE.

MAN'S SENSITIVITY IS GREATEST FOR ROTATION ABOUT THE PITCH AXIS AND LEAST FOR ROTATION ABOUT THE ROLL AXIS.

THE AUTHOR STATES THAT, SINCE 1955 A NUMBER OF RESEARCH STUDIES HAVE BEEN ACCOMPLISHED BY THE AIR FORCE, NAVY, ARMY, NASA AND VARIOUS UNIVERSITY GROUPS CONCERNING THE VALUE OF MOTION IN FLIGHT SIMULATORS. IN EVERY CASE KNOWN TO THE AUTHOR THE DESIRABILITY FOR INCLUDING MOTION IN FLIGHT SIMULATORS AND TRAINERS WAS REAFFIRMED AND ED LINK'S HUNCH WAS FINALLY VALIDATED.

L.E. FOGARTY - GROUND AIRCRAFT TRAINER
PATENT NO. 2,930,144
FILED JULY 6, 1954 GRANTED MARCH 29, 1960

NO ABSTRACT

FORBES, A.R. SURVEY OF THE EFFECTS OF BUFFETING AND VIBRATION ON HUMAN BEHAVIOR, FPRC MEMORANDUM NO. 105, FLYING PERSONNEL RESEARCH COMMITTEE, INSTITUTE OF AVIATION MEDICINE, ROYAL AIR FORCE, FARNBOROUGH, ENGLAND, AD 317 618, AUGUST 1959.
(CONFIDENTIAL)

NO ABSTRACT GIVEN

FRIEDLAND, B. AND LING, C.K. QUASI-OPTIMUM DESIGN OF CONTROL SYSTEMS FOR MOVING-BASE SIMULATORS REPORT NO. NASA CR-1613 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, AMES RESEARCH CENTER, OCTOBER 1970

* ABSTRACT *

THIS REPORT IS CONCERNED WITH THE OPTIMAL CONTROL OF A SIX-DEGREE-OF-FREEDOM MOVING-BASE SIMULATOR, AND UTILIZES THE QUASI-OPTIMAL CONTROL METHOD DUE TO FRIEDLAND. THE PROBLEM, IN BROAD TERMS, IS TO DETERMINE A CONTROL LAW FOR MOVING THE SIMULATOR CAB SO THAT ITS MOTION WILL: (1) 'BEST' APPROXIMATE THE DESIRED AIRCRAFT RESPONSE, AND (2) NOT EXCEED THE LIMITED TRANSLATIONAL CAPABILITY OF THE SIMULATOR. DUE TO LACK OF EXPERIMENTAL DATA, 'BEST' CAN ONLY BE INTERPRETED SUBJECTIVELY AT THE PRESENT TIME. BY USE OF THE METHOD, A VARIETY OF QUASI-OPTIMAL RESPONSES, EACH EMPHASIZING DIFFERENT FEATURES THOUGHT TO BE IMPORTANT IN MOTION PERCEPTION, HAVE BEEN OBTAINED. EXAMPLES OF SUCH RESULTS ARE GIVEN, AND THE CONSIDERATIONS IMPORTANT IN INITIAL SUBJECTIVE EVALUATIONS BY EXPERIENCED FLIGHT PERSONNEL ARE DISCUSSED. FINAL EVALUATION MUST BE MADE BY ACTUAL EXPERIMENTS IN A MOTION SIMULATOR.

FRIEDLAND, B., LING, CHONG-KUAN AND HUTTON, MAURICE F. QUASI-OPTIMUM DESIGN OF A SIX DEGREE OF FREEDOM MOVING BASE SIMULATOR REPORT NO. NASA CR-2312, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D.C. 20546, OCTOBER 1973.

* ABSTRACT *

THE DESIGN OF A WASHOUT CONTROL SYSTEM FOR A MOVING-BASE SIMULATOR IS TREATED BY A QUASI-OPTIMUM CONTROL TECHNIQUE DEVELOPED BY FRIEDLAND (NASA CR-527 AND CR-1009). AN EARLIER VERSION OF THE WASHOUT SYSTEM, LIMITED TO LONGITUDINAL MOTION, WAS DESCRIBED IN NASA CR-1613 AND THIS WORK EXTENDS THE DESIGN TO A COMPLETE SIX-DEGREE-OF-FREEDOM SIMULATOR. THE BROAD OBJECTIVE OF THE DESIGN IS TO REPRODUCE THE SENSED MOTION (ANGULAR VELOCITY AND SPECIFIC FORCE) AS ACCURATELY AS POSSIBLE WITHOUT CAUSING THE SIMULATOR (CAB) EXCURSIONS TO EXCEED SPECIFIED LIMITS. A PERFORMANCE CRITERION IS ESTABLISHED THAT WEIGHS MAGNITUDE AND DIRECTION ERRORS IN SPECIFIC FORCE AND IN ANGULAR VELOCITY AND ATTEMPTS TO MAINTAIN THE EXCURSION WITHIN SET LIMITS BY PENALIZING EXCESSIVE EXCURSIONS. A FORTRAN ROUTINE FOR REALIZING THE WASHOUT LAW WAS DEVELOPED AND TYPICAL TIME-HISTORIES USING THE WASHOUT ROUTINE WERE SIMULATED FOR A RANGE OF PARAMETERS IN THE PENALTY AND WEIGHTING FUNCTIONS. THESE TIME HISTORIES AND THE LISTING OF THE ROUTINE ARE INCLUDED IN THE REPORT. EVALUATION OF THIS CLASS OF WASHOUT LAWS IN ACTUAL PILOT SIMULATIONS WAS NOT UNDERTAKEN, AND SUCH EVALUATION IS RECOMMENDED FOR FUTURE INVESTIGATION.

FRIEDLAND, B., THAU, F.E., COHEN, V.D., AND ELLIS, J. STUDY OF QUASI-OPTIMUM FEEDBACK CONTROL TECHNIQUES. NASA REPORT CR-527, AMES RESEARCH CENTER, AUG. 1966.

* ABSTRACT *

A MAJOR LIMITATION TO THE USE OF MODERN VARIATIONAL CONTROL THEORY FOR THE DESIGN OF PRACTICAL FEEDBACK CONTROL SYSTEMS IS THE NEED TO SOLVE A TWO-POINT BOUNDARY-VALUE PROBLEM OF DIFFERENTIAL EQUATIONS IN REAL TIME. IN MOST SITUATIONS, THE REALIZATION OF THE EXACT SOLUTION TO THE TWO-POINT BOUNDARY-VALUE IS NOT FEASIBLE IN VIEW OF THE COST AND SIZE OF EQUIPMENT WHICH SUCH A COMPUTATION WOULD ENTAIL. MOREOVER, THE OPTIMUM PERFORMANCE, IN MANY INSTANCES, IS ONLY NEGLIGIBLY SUPERIOR TO THAT OBTAINABLE WITH A SIMPLER, NON-OPTIMUM CONTROL COMPUTATION. FOR THIS REASON MOST PRACTICAL FEEDBACK CONTROL SYSTEMS CONTINUE TO BE DESIGNED BY CONVENTIONAL FREQUENCY-DOMAIN OR CUT-AND-TRY TECHNIQUES. THERE IS AMPLE EVIDENCE, HOWEVER, OF THE SHORTCOMINGS OF CONVENTIONAL TECHNIQUES FOR THE DESIGN OF CONTROL SYSTEMS FOR COMPLEX PROCESSES; A CLEAR NEED EXISTS FOR DESIGN TECHNIQUES WHICH EMPLOY THE MODERN VARIATIONAL APPROACH BUT DO NOT ENTAIL THE SOLUTION OF A COMPLEX TWO-POINT BOUNDARY-VALUE PROBLEM. THIS NEED MOTIVATED THE QUASI-OPTIMUM CONTROL TECHNIQUE OF THIS STUDY.

 FRIEDLAND, B., THAU, F.E., WELT, S., LING, C.K., AND SCHILDER, M. ADDITIONAL STUDIES OF QUASI-OPTIMUM FEEDBACK CONTROL TECHNIQUES. TECH. REPORT NASA CR-1099, AMES RESEARCH CENTER, JULY 1968.

* ABSTRACT *

THE BASIS OF THE QUASI-OPTIMUM CONTROL TECHNIQUE UNDER INVESTIGATION IS THE WELL ESTABLISHED ENGINEERING PRACTICE OF APPROXIMATING A COMPLICATED DYNAMIC PROCESS BY A SIMPLER PROCESS, DESIGNING A CONTROL SYSTEM FOR THE LATTER, AND THEN AMENDING THE DESIGN, IF NECESSARY, TO ACCOUNT FOR THE DIFFERENCE BETWEEN THE ORIGINAL PROCESS AND THE APPROXIMATION USED. A SYSTEMATIC APPLICATION OF THIS DESIGN APPROACH, WITHIN THE FRAMEWORK OF MODERN OPTIMUM CONTROL THEORY IS THE ESSENCE OF THE QUASI-OPTIMUM CONTROL TECHNIQUE. IN THE APPLICATION OF THIS TECHNIQUE IT IS NECESSARY THAT THE 'SIMPLIFIED PROCESS', IN ADDITION TO BEING A REASONABLY FAITHFUL REPRESENTATION OF THE TRUE PROCESS, MUST BE SUCH THAT THE SOLUTION OF THE TWO-POINT BOUNDARY-VALUE PROBLEM GOVERNING ITS OPTIMUM CONTROL LAW CAN BE REDUCED TO MANAGEABLE PROPORTIONS. THE CORRECTION TO THE OPTIMUM CONTROL LAW THEN REQUIRES THE EVALUATION OF A CORRECTION MATRIX BY THE SOLUTION OF A MATRIX RICCATI EQUATION. THE SOLUTION MATRIX OF THIS RICCATI EQUATION IS USED TO CORRECT THE SOLUTION TO THE SIMPLIFIED PROCESS.

 FROST, G. MAN-MACHINE DYNAMICS. IN VAN COTT, H.P. AND KINKADE, R.G. (EDS) 'HUMAN ENGINEERING GUIDE TO EQUIPMENT DESIGN', SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASH., D.C., 1972.

* ABSTRACT *

THIS CHAPTER IDENTIFIES AND DISCUSSES THE FACTORS AFFECTING HUMAN PERFORMANCE IN TRACKING AND WATCHKEEPING (VIGILANCE) TASKS AND PRESENTS DESIGN TECHNIQUES FOR OPTIMIZING THE PERFORMANCE OF MAN-MACHINE SYSTEMS WHEREVER POSSIBLE; OTHERWISE, GENERAL DESIGN RECOMMENDATIONS ARE MADE AND THE AVAILABLE RESEARCH RESULTS ARE REFERENCED.

CONTENTS

6.1	THE CLOSED-LOOP MANUAL-TRACKING SYSTEM	229
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FRY, E.B. ET. AL. 'USE OF A SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR FOR VTOL HOVERING TASKS', NASA TN-D-5383, AUGUST, 1969.

* ABSTRACT *

A PILOTTED, SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR HAS BEEN EVALUATED WITH REGARD TO ITS ABILITY TO SIMULATE VTOL VISUAL HOVERING TASKS. CHARACTERISTICS OF THE VARIABLE-STABILITY JET LIFT BELL X-14A AIRCRAFT WERE SIMULATED AND RESULTS FOR THE ROLL AND PITCH AXES WERE COMPARED WITH FLIGHT DATA. THE ROLL-AXIS DATA WERE ALSO COMPARED WITH DATA FROM TWO AND SINGLE DEGREE OF FREEDOM SIMULATORS.

CONTROL POWER AND DAMPING REQUIREMENTS FOR THE ROLL AND PITCH AXES COMPARED VERY WELL WITH FLIGHT DATA. THE SIMULATOR'S MOTION QUALITY WAS CONSIDERED OUTSTANDING FOR VTOL HOVERING FLIGHT. ITS TRAVEL LIMITS WERE LARGE ENOUGH TO SIMULATE HOVER-MANEUVER TASKS ON A ONE-TO-ONE SCALE, THAT IS, WITH OUT THE NEED FOR ANY ATTENUATION OF THE DRIVE SIGNALS.

ROLL-LATERAL MOTIONS (TWO-DEGREE-OF-FREEDOM MOTIONS) GAVE ESSENTIALLY THE SAME RESULTS AS SIX-DEGREES OPERATION FOR EVALUATION OF ROLL-AXIS MANEUVERS.

FUIT, I., WILLIGES, R.C. AND ROBCOE, S.N. UNIVERSITY OF ILLINOIS, URBANA-CHAMPAIGN. 'AIRCRAFT SIMULATOR MOTION AND THE ORDER OF MERIT OF FLIGHT ATTITUDE AND STEERING GUIDANCE DISPLAYS'. IN HUMAN FACTORS, VOL. 17(4), 1975, PAGES 388-400.

* ABSTRACT *

TWENTY-FOUR NON PILOT VOLUNTEER SUBJECTS WERE TESTED ON THREE FLIGHT TASKS WHILE FLYING FOUR BASIC AIRCRAFT ATTITUDE PRESENTATIONS (MOVING HORIZON, MOVING AIRPLANE, FREQUENCY SEPARATED AND KINALOG) IN A LIGHT TWIN-ENGINE AIRCRAFT SIMULATOR PROVIDING THREE LEVELS OF MOTION CUES (NO MOTION,

STANDARD GAT-2 MOTION, AND WASHOUT MOTION). THE FLIGHT TASKS INVOLVED CONFLICTING VISUAL AND VESTIBULAR CUES AND INCLUDED DISTURBED ATTITUDE TRACKING, COMMAND FLIGHT PATH TRACKING IN BOTH PURSUIT AND COMPENSATORY MODES, AND A SERIES OF RECOVERY TRIALS FROM DISCRETE UNKNOWN ATTITUDES. TO PROVIDE A BASIS FOR COMPARISON, THE PRESENT SIMULATOR STUDY CLOSELY REPLICATED THE PROCEDURES USED IN THE RUSCOE AND WILLIGES (1973) FLIGHT EXPERIMENT. THE FREQUENCY-SEPARATED DISPLAY PROVIDED PERFORMANCES AT LEAST EQUIVALENT AND IN SOME CASES SUPERIOR TO THOSE OBTAINED WITH THE CONVENTIONAL MOVING HORIZON DISPLAY. EITHER TYPE OF SIMULATOR MOTION RESULTED IN BETTER DISTURBED ATTITUDE TRACKING PERFORMANCE THAN NO MOTION, AND WASHOUT MOTION PROVIDED STEREOTYPE CONTROL RESPONSES IN RECOVERY FROM UNKNOWN ATTITUDES MOST CLOSELY CORRESPONDING TO THOSE OBTAINED IN FLIGHT. IT WAS CONCLUDED THAT CARE MUST BE USED IN GENERALIZING SIMULATOR RESULTS TO FLYING PERFORMANCE WHEN NO PHYSICAL MOTION CUES OR INAPPROPRIATE ONES ARE PRESENT IN THE SIMULATOR.

FULLER, R.G. AN EVALUATION OF THE FIDELITY OF MOTION SIMULATORS USING A MODEL OF HUMAN DYNAMIC ORIENTATION. NAVAL POSTGRADUATE SCHOOL, MONTEREY, CALIFORNIA. MASTER'S THESIS, SEPTEMBER 1977

* ABSTRACT *

A DETERMINISTIC SIMULATION USING A MODEL OF HUMAN DYNAMIC ORIENTATION WAS WRITTEN TO OPTIMIZE THE PARAMETERS OF THE MOTION BASE CONTROL SYSTEM FOR A SIX-DEGREE-OF-FREEDOM FLIGHT SIMULATOR. AN EXPERIMENT REQUIRING PILOTS TO RATE DIFFERENT LEVELS OF MOTION FIDELITY DURING A BASIC FLIGHT TASK PROVIDED A DATA BASE FOR VALIDATION OF THE SIMULATION. RATINGS BETWEEN SUBJECTS FOR LINEAR, ROTATIONAL, AND COMBINED MOTION CUES WERE INCONSISTENT DUE, IN PART, TO THE SUBJECTS' LACK OF EXPERIENCE IN THE F-15 AIRCRAFT AND PROFICIENCY IN HIGH PERFORMANCE AIRCRAFT. THE COEFFICIENT OF CONCORDANCE AMONG SUBJECTS FOR THE THREE RATINGS WERE .4483, .4835, AND .5914, RESPECTIVELY. COMPARISON OF SIMULATION RESULTS WITH EXPERIMENTAL DATA YIELDED POSITIVE CORRELATIONS AS HIGH AS .5138. RESPONSE OF THE SIMULATION TO CHANGING WASH-OUT FILTER PARAMETERS WAS INVESTIGATED AND FOUND TO BE ADAPTABLE TO EXPERIMENTAL OPTIMIZATION METHODS.

GAGNE, R.M. TRAINING DEVICES AND SIMULATORS: SOME RESEARCH ISSUES. AMERICAN PSYCHOLOGIST, VOL. 9, NO. 3, PP. 95-107, MARCH 1954.

* ABSTRACT *

THIS PAPER ATTEMPTS TO DESCRIBE AND CLARIFY SOME RESEARCH ISSUES WHICH OCCUR IN CONNECTION WITH THE DEVELOPMENT, USE AND EVALUATION OF TRAINING DEVICES. THE PURPOSE IS TO SEE WHETHER

SUCH CLARIFICATION CAN REVEAL A FRAMEWORK FOR PSYCHOLOGICAL RESEARCH IN THE TRAINING DEVICES AREA.

IT IS MAINTAINED THAT THE KINDS OF UTILIZATION OF TRAINING DEVICES ARE TWO: PERFORMANCE MEASUREMENT AND PERFORMANCE IMPROVEMENT. ALTHOUGH THE TWO USES ARE FREQUENTLY MADE OF A SINGLE PIECE OF EQUIPMENT, THEY MAY BE DISTINGUISHED PARTICULARLY IN THE CHARACTERISTICS OF THE DEVICE WHICH ARE ESSENTIAL FOR EACH PURPOSE. WHEN THE DEVICE IS USED FOR PERFORMANCE MEASUREMENT, THE IMPORTANT CHARACTERISTICS ARE RELIABILITY AND VALIDITY. WHEN THE DEVICE IS EMPLOYED FOR IMPROVING PERFORMANCE, ON THE OTHER HAND, THE CHARACTERISTIC OF IMPORTANCE IS THE AMOUNT OF TRANSFER OF LEARNING TO AN OPERATIONAL TASK. IN EITHER CASE, DEGREE OF SIMULATION BECOMES A SECONDARY CONSIDERATION.

WHEN ONE CONSIDERS THESE PURPOSES, SOME OF THE OPPORTUNITIES FOR RESEARCH ON TRAINING DEVICES BECOME APPARENT. ON THE SIDE OF METHODOLOGY, THE RANGE OF THESE PROBLEMS INCLUDES JOB ANALYSIS, TRAINING, PROFICIENCY MEASUREMENT AND CRITERION DEVELOPMENT. ON THE SIDE OF THEORY, QUESTIONS MENTIONED IN THE PRESENT DISCUSSION INCLUDE THOSE OF THE STRUCTURE OF SKILLS, THE DETERMINANTS OF HUMAN VARIABILITY, RELATIONSHIPS OF SET AND MOTIVATION TO LEARNING, AND THE MECHANISMS OF TRANSFER OF LEARNING.

GALLAGHER, J.T. REQUIREMENTS ON SIMULATORS USED IN HANDLING QUALITIES RESEARCH. AIAA PAPER 70-353, 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE', CAPE CANAVERAL, FL, MAR 16-18 1970.

* ABSTRACT *

THE NORTHROP LARGE AMPLITUDE 3-AXIS FLIGHT SIMULATOR AND THE NORTHROP ROTATIONAL 3-AXIS FLIGHT SIMULATOR ARE DISCUSSED IN SUFFICIENT DETAIL TO PROVIDE A BASIS FOR UNDERSTANDING THE CONSTRAINTS PLACED ON VALID SIMULATION WHEN USING EXISTING GROUND-BASED SIMULATION EQUIPMENT. THE PHYSICAL CONSTRAINTS ARE OUTLINED AND METHODOLOGY IS DISCUSSED WHICH HAS BEEN DEVELOPED AT NORTHROP FOR DRIVING THE VISUAL DISPLAY AND MOTION SYSTEMS TO MINIMIZE THE IMPACT OF THE CONSTRAINTS. IT IS SHOWN THAT THE SAME BASIC TECHNIQUE OF DRIVING THE HARDWARE IS SATISFACTORY FOR BOTH SIMULATORS. IN EXPLAINING THE DRIVE TECHNIQUE, A SIMPLE MODEL OF THE SENSING MECHANISMS OF THE VESTIBULAR SYSTEM IS USED. WHILE THIS MODEL HAS BEEN USEFUL IN UNDERSTANDING THE PHYSICS OF THE TECHNIQUE, A WAY HAS NOT BEEN FOUND YET TO TAKE ADVANTAGE OF THE VESTIBULAR SYSTEM DESCRIPTION TO ESTABLISH THE DYNAMIC PERFORMANCE REQUIRED OF THE ELEMENTS IN THE MOTION AND VISUAL DISPLAY SYSTEM. THE SUCCESS OF THE DRIVE SCHEME DEPENDS ON SUBJECTIVE OBSERVATIONS OF TEST PILOTS WHICH ALLOW FILTERS USED IN THE DRIVES TO BE PROPERLY SET IN TERMS OF GAIN AND BREAK FREQUENCY. IT IS

SHOWN THAT THE FILTER CHARACTERISTICS ARE NOT ONLY DETERMINED SUBJECTIVELY BUT ARE TASK DEPENDENT. TWO EXPERIMENTS CONDUCTED ON THE SIMULATORS ARE BRIEFLY DISCUSSED TO PROVIDE SOME ASSURANCE THAT THE DRIVE TECHNIQUE WORKS WITHIN THE CONSTRAINTS OF SUBJECTIVITY AND TASK DEPENDENCE.

FOLLOWING THIS, THE FIRST OF A SERIES OF EXPERIMENTS BEING CONDUCTED ON THE LARGE AMPLITUDE 3-AXIS FLIGHT SIMULATOR TO DEVELOP A RATIONALE FOR MOTION AND VISUAL DISPLAY DRIVES FOR MOVING BASE SIMULATORS IS DISCUSSED IN WHICH A COMPREHENSIVE SIMULATION OF THE CORNELL T-33 INFLIGHT SIMULATOR (1) HAS BEEN MECHANIZED AND IS BEING FLOWN ON THE NORTHROP LARGE AMPLITUDE 3-AXIS FLIGHT SIMULATOR. FLIGHT EXPERIMENTS REPORTED IN REF (1) HAVE BEEN REPEATED ON THE SIMULATOR. PILOT RATING, CONTROL SENSITIVITY, AND PILOT COMMENTS ARE SHOWN TO JUSTIFY THE METHOD OF INTEGRATING THE MATHEMATICAL MODEL OF THE T-33, THE MOTION SYSTEM, AND THE VISUAL DISPLAY SYSTEM OF THE SIMULATOR. FOLLOWING THESE PRELIMINARY EXPERIMENTS, COMPREHENSIVE TESTING WILL BE CONDUCTED TO PROVIDE A CATALOGUE OF DRIVE SYSTEM CHARACTERISTICS WHICH ARE TASK-DEPENDENT AND CAN BE USED IN APPLICATION OF MOTION-BASE SIMULATORS TO HANDLING QUALITIES RESEARCH.

BASED ON EXPERIENCE IN THIS WORK, IT IS SUGGESTED THAT A MIX OF SIMULATORS BE USED TO STUDY THE PROBLEMS ASSOCIATED WITH FIGHTER-BOMBER MISSION EFFECTIVENESS AND HANDLING QUALITIES. (AUTHOR; QUOTATIONS OURS.)

REF (1) AFFDL-TR-67-98: INFLIGHT EVALUATION OF LATERAL-DIRECTIONAL HANDLING QUALITIES FOR THE FIGHTER MISSION

*ALSO IN J. AIRCRAFT, VOL. 8, NO. 11, NOV 1971

GALLAGHER, J.T. AND NELSON, W. USE OF SIMULATORS IN THE DESIGN AND DEVELOPMENT OF FLIGHT CONTROL SYSTEMS. 'SOCIETY OF AUTOMOTIVE ENGINEERS', NATIONAL AEROSPACE ENGINEERING AND MANUFACTURING MEETING, LOS ANGELES, CALIFORNIA, OCTOBER 16-18, 1973, PAPER NO. 730933.

* ABSTRACT *

RECENT ADVANCES IN THE DESIGN AND DEVELOPMENT OF MOTION SIMULATORS, VISUAL DISPLAY SYSTEMS, ARTIFICIAL FORCE PRODUCERS, AND COMPUTER CAPABILITY HAVE ENHANCED THE EFFECTIVENESS OF GROUND-BASED SIMULATORS IN THE DESIGN PROCESS. AT NORTHROP, A SYSTEMATIC IMPROVEMENT IN SIMULATOR SUBSYSTEMS HAS RESULTED IN THE EXISTENCE OF THE NORTHROP LARGE AMPLITUDE THREE-AXIS FLIGHT SIMULATOR WHICH HAS 6 DEGREES OF FREEDOM. THE SIMULATOR IS A SIGNIFICANT TOOL IN THE DESIGN OF FLIGHT CONTROL SYSTEMS, PARTICULARLY IN TODAY'S ENVIRONMENT WHERE THE AEROSPACE INDUSTRY IS ATTEMPTING TO EXTEND THE PERFORMANCE ENVELOPES OF ITS PRODUCTS THROUGH THE USE OF NONCONVENTIONAL CONFIGURATIONS

AND RADICAL FLIGHT CONTROL SYSTEM CONCEPTS. SOME EXAMPLES ARE PRESENTED IN THIS PAPER TO DEMONSTRATE THE CONTRIBUTION THAT THE NORTHROP LARGE AMPLITUDE THREE-AXIS FLIGHT SIMULATOR IS MAKING IN THE YF-17 PROGRAM TO THE SOLUTION OF CURRENT FLIGHT CONTROL SYSTEM PROBLEMS THAT ARE NOT SOLUBLE BY ANALYTICAL TECHNIQUES.

GALLAGHER, P.D., HUNT, R.A. AND WILLIGES, R.C. A REGRESSION APPROACH TO GENERATE AIRCRAFT PREDICTOR INFORMATION. AVIATION RESEARCH LABORATORY INSTITUTE OF AVIATION, UNIVERSITY OF ILLINOIS, SAVOY. FOR THE OFFICE OF NAVAL RESEARCH. TECHNICAL REPORT NO. ARL-76-11/ONR-76-2, JULY 1976.

* ABSTRACT *

A PREDICTOR DISPLAY SHOWS THE HUMAN OPERATOR FUTURE CONSEQUENCES OF HIS IMMEDIATE CONTROL INPUT. A CONTACT ANALOG AIRCRAFT DISPLAY IS DESCRIBED IN WHICH AN AIRPLANE-LIKE PREDICTOR SYMBOL DEPICTS FUTURE AIRPLANE POSITION AND ORIENTATION. THE STANDARD METHOD FOR OBTAINING THE PREDICTOR INFORMATION IS TO USE A COMPLETE, FAST-TIME MODEL OF THE CONTROLLED VEHICLE. AN ALTERNATIVE APPROACH IS PRESENTED IN THIS PAPER IN WHICH LEAST SQUARES, FIRST ORDER, LINEAR APPROXIMATIONS FOR EACH OF THE SIX DEGREES OF FREEDOM OF AIRCRAFT MOTION WERE CALCULATED. THIRTEEN VARIABLES REPRESENTING CHANGES IN POSITIONS AND RATE OF CHANGE OF POSITIONS WERE SELECTED AS PARAMETERS FOR THE PREDICTION EQUATIONS. SEPARATE SETS OF EQUATIONS WERE DETERMINED FOR 7, 14, AND 21 SECONDS PREDICTION TIMES AND CONTINUOUS 1 AND 3 SECONDS CONTROL NEUTRALIZATION ASSUMPTION TIMES. THE ADVANTAGES AND DISADVANTAGES OF THIS REGRESSION APPROACH ARE DISCUSSED.

GARREN, J.F., JR., AND ASSADOURIAN, A. VTOL HEIGHT CONTROL REQUIREMENTS IN HOVERING AS DETERMINED FROM MOTION SIMULATOR STUDY. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TECH. NOTE TN D-1488, OCT 1962.

* ABSTRACT *

HEIGHT-CONTROL REQUIREMENTS WITH RESPECT TO OPTIMUM CONTROL SENSITIVITY, MAXIMUM THRUST-WEIGHT RATIO, VERTICAL-VELOCITY DAMPING, CONTROL-SYSTEM TIME DELAY, AND GROUND EFFECT HAVE BEEN INVESTIGATED FOR STILL AIR. THE EVALUATION WAS BASED ON THE CONTROLLABILITY PROVIDED BY EACH TEST COMBINATION DURING THE EXECUTION OF SMALL BUT RAPID AND PRECISE ALTITUDE CHANGES. SATISFACTORY CONTROL FOR A WELL-DAMPED AIRCRAFT WAS OBTAINED BY A MINIMUM THRUST-WEIGHT RATIO OF APPROXIMATELY 1.08 WITHOUT BENEFIT OF STORED ENERGY. A DAMPING-MASS RATIO OF ABOUT 0.2 PER SECOND WAS FOUND TO BE A MINIMUM TO OBTAIN SATISFACTORY

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CONTROL. INTRODUCTION OF A CONTROL-SYSTEM TIME DELAY RESULTED IN A RAPID DETERIORATION IN HOVERING CONTROLLABILITY. THE ADDITION OF STABLE GROUND EFFECT TO THE SIMULATION SLIGHTLY IMPROVED THE HOVERING CONTROLLABILITY FOR ALL THE CONDITIONS OF DAMPING TESTED.

GASTROCK, B.A. AND BURTON, R. LIMITED NAVY EVALUATION OF THE S-3A WEAPONS SYSTEM TRAINER (WST) (DEVICE 2F92). NAVAL AIR TEST CENTER, PATUXENT RIVER MD. REPORT NO. NATC-FT-47R-74, JUNE 1974

* ABSTRACT *

THIS EVALUATION WAS CONDUCTED TO DETERMINE SUITABILITY OF THE WST FOR OPERATIONAL USE AS AN S-3A AIRPLANE AND ASW TACTICAL TRAINING DEVICE. THE S-3A WST EXHIBITED HIGH POTENTIAL FOR S-3A/ASW MISSION TACTICAL TRAINING UPON CORRECTION OF CERTAIN DEFICIENCIES. THE EXCELLENT SIMULATION OF AIRCRAFT MOTION CUES IS AN ENHANCING CHARACTERISTIC OF THE S-3A WST WHICH SHOULD BE INCORPORATED IN FUTURE FLIGHT SIMULATIONS. THE MAJOR DEFICIENCIES DISCOVERED WERE DUE TO CONTROL SYSTEM AND AERODYNAMIC SIMULATION DISCREPANCIES. THE MOST SIGNIFICANT AERODYNAMIC SIMULATION DEFICIENCY WAS ITS INABILITY TO SIMULATE THE STALL CHARACTERISTICS OF THE S-3A. CONTROL SYSTEM DISCREPANCIES RESULTED IN LATERAL AND LONGITUDINAL CONTROL SENSITIVITY PROBLEMS AND UNREALISTIC CONTROL MOVEMENTS DURING THE APPROACH AND LANDING PHASE.

A.J. GAYON - MOTION SIMULATOR
PATENT NO. 3,559,936
FILED NOV. 26, 1968 GRANTED FEB. 2, 1971

NO ABSTRACT

GEISSE, J.H. - AVIATION GROUND TRAINING MACHINE
PATENT NO. 2,323,322
FILED MAY 22, 1942 GRANTED JULY 6, 1943

NO ABSTRACT

J.H. GEISSE - SYNTHETIC FLIGHT TRAINERS
PATENT NO. 2,924,028
DATE FILED - JAN 10, 1958 DATE GRANTED - FEB. 9, 1960

NR ABSTRACT

GELCARD, F.A. 'THE HUMAN SENSES'. NEW YORK: JOHN WILEY, 1972.

* ABSTRACT *

THE HUMAN SENSES ARE TREATED PSYCHOLOGICALLY, PSYCHOPHYSICALLY, AND NEUROPHYSIOLOGICALLY. THROUGHOUT, THE GOAL IS MAINTAINED OF EVALUATING THE PRESENT STANCE IN SENSORY PSYCHOPHYSIOLOGY. THE CHAPTERS CONCERNING: 'THE SKIN AND ITS STIMULI', 'PRESSURE SENSITIVITY', 'KINESTHETIC AND ORGANIC SENSIBILITIES', AND 'VESTIBULAR SENSITIVITY' ARE OF PARTICULAR INTEREST IN THE STUDY OF MOTION SIMULATION.

CELLER, R.E., SMITH, J.F., KRON, G.A., BDIERNA, A.V. AND MENDES, E.G. FUTURE UNDERGRADUATE PILOT TRAINING (UPT) STUDY. PHASE II SUMMARY REPORT, APPENDIX II, VOL. II, REPORT LR-23918-2-VOL-2. AERONAUTICAL SYSTEMS DIV., WRIGHT-PATTERSON AFB, OH, AD-882 292, FEB 1971.

* ABSTRACT *

THE REPORTS INCLUDED IN THIS VOLUME DOCUMENT RESEARCH CONDUCTED TO PROVIDE AN ASSESSMENT OF SIMULATION REQUIREMENTS AND TECHNOLOGY TO AID IN SELECTING CANDIDATE SYSTEMS FOR THE 1975-1990 TIME FRAME. THE FOLLOWING TOPICS ARE COVERED;

- (1) SIMULATION REQUIREMENTS AND TECHNOLOGY
- (2) FIDELITY OF AIRCRAFT SIMULATION
- (3) SIMULATION OF MOTION
- (4) VISUAL SIMULATION
- (5) SUBSYSTEM RESEARCH
- (6) EVALUATION OF ADAPTIVE TRAINING
- (7) OTHER TRAINING FEATURES
- (8) COMPUTER REQUIREMENTS AND TECHNOLOGY.

GERATHEWHL, S.C. 'FIDELITY OF SIMULATION AND TRANSFER OF TRAINING: A REVIEW OF THE PROBLEM' DEPARTMENT OF TRANSPORTATION, FEDERAL AVIATION ADMINISTRATION, OFFICE OF AVIATION MEDICINE. DECEMBER 1969. REPORT NO. AM 69-24

* ABSTRACT *

IN GENERAL IT CAN BE STATED THAT THE AMOUNT OF TRANSFER EXPECTED TO OCCUR IN FLIGHT SIMULATOR APPLICATION SEEMS TO BE PROPORTIONAL TO THE DEGREE OF FIDELITY PROVIDED. ALTHOUGH PART-TASK SIMULATORS ARE USUALLY LESS EXPENSIVE AND OF LOWER FIDELITY THAN WHOLE-TASK SIMULATORS, THEY CAN BE VERY USEFUL FOR THE LEARNING OF SPECIFIC TASKS. HOWEVER, THEIR SHORT-

COMINGS, AS CLEARLY DEMONSTRATED BY ADAMS CAN BE TRACED BACK TO THE LACK OF FIDELITY, PARTICULARLY IN SIMULATING MOTION.

IT SEEMS THAT THE WHOLE TASK FLIGHT SIMULATOR DERIVES ITS ADVANTAGES AS A TRAINING DEVICE PRIMARILY FROM THE INCORPORATION OF MOTION CUES, IF THE ADDITION OF COMPLEX MOTION VECTORS INCREASES THE FIDELITY OF THE SIMULATION AND DOES NOT RESULT IN SPURIOUS STIMULI. THE VARIOUS PERCEPTUAL PHENOMENA, PHYSIOLOGICAL EFFECTS AND PERFORMANCE CHANGES OBSERVED IN COMPLEX SIMULATORS INDICATE THAT IT IS THE PSYCHOLOGIC, PHYSIOLOGIC, AND OPERATIONAL REALISM WHICH DETERMINE FIDELITY IN SIMULATION AND NOT FACE VALIDITY BASED ON PHYSICAL SIMILARITY OF THE DEVICES.

THERE ARE TWO ADDITIONAL FACTORS WHICH MUST BE MENTIONED IN THIS CONTEXT, NAMELY, MOTIVATION AND DANGER. ELSOM HAS POINTED OUT THAT A CERTAIN DEGREE OF STRESS IS NECESSARY IN ORDER TO MOTIVATE THE PILOT WHO WORKS IN THE SIMULATOR. PHYSICAL IDENTITY ALONE IS NOT ENOUGH TO GENERATE MOTIVATION AND ACCEPTANCE. THE QUESTION WHETHER DANGER MUST BE INVOLVED IN ORDER TO PRODUCE FIDELITY IS NOT EASY TO ANSWER. EXPERIENCE IN THE TRAINING OF ASTRONAUTS SEEMS TO INDICATE THAT DANGER IS NOT A NECESSARY PREREQUISITE FOR THE TRANSFER OF TRAINING.

IN CLOSING IT IS RECOMMENDED THAT AN OPTIMUM DEGREE OF FIDELITY BE PROVIDED IN ORDER TO OBTAIN A MAXIMUM AMOUNT OF TRANSFER. IN CERTAIN INSTANCES, THIS CAN BE ACHIEVED SIMPLY BY PART-TASK SIMULATION; IN MOST CASES, HOWEVER, THE USE OF A WHOLE-TASK OR EVEN INFLIGHT FLIGHT SIMULATORS MAY BE OPTIMUM. THIS LATTER DEVICE CAN PROVIDE FOR THE HIGHEST DEGREE OF FIDELITY, BUT IT IS GENERALLY THE MOST COMPLEX, COMPLICATED AND EXPENSIVE TYPE OF SIMULATOR. FOR CERTAIN TYPES OF TRAINING, FOR EXAMPLE SST PILOT TRAINING, A COMBINATION OF GROUND-BASED WHOLE-TASK AND INFLIGHT SIMULATORS WILL BE USED. THIS APPROACH IS STRAIGHT FORWARD BY PROCEEDING FROM THE AIRCRAFT WHICH IS APPARENTLY EASIER TO HANDLE THAN THE MORE DIFFICULT ONE. IT IS BASED ON THE BEST JUDGEMENTS OF QUALIFIED TEST PILOTS AND ON FACE VALIDITY. A GENERAL SCIENTIFIC THEORY WHICH ACCURATELY PREDICTS THE OPTIMUM DEGREE OF FIDELITY NEEDED TO ACHIEVE THE MAXIMUM OF TRANSFER IN FLIGHT TRAINING HAS STILL TO BE DEVELOPED.

GERDES, R.M. A PILOTED MOTION SIMULATOR INVESTIGATION OF VTOL HEIGHT-CONTROL REQUIREMENTS, NASA-TN-D-2451, AUGUST 1964.

* ABSTRACT *

A MOVING-COCKPIT PILOTED SIMULATOR WAS USED TO INVESTIGATE VTOL AIRCRAFT HEIGHT CONTROL REQUIREMENTS DURING HOVER. PILOT OPINION RATINGS WERE USED TO DETERMINE THE RELATIONSHIPS OF CONTROL POWER, DAMPING, AND TIME CONSTANT IN REALISTIC VTOL HOVERING TASKS. THE MINIMUM UPWARD ACCELERATION FOR NORMAL

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OPERATION' WAS FOUND TO BE 1.06G WHILE MINIMUM ACCEPTABLE SAFE OPERATION WAS DETERMINED TO BE BETWEEN 1.02G AND 1.03G. MINIMUM DAMPING LEVELS FOR NORMAL OPERATION WERE DEPENDENT ON CONTROL SYSTEM TIME CONSTANT WHEN OPERATING WITH HIGH THRUST-TO-WEIGHT RATIOS. ACCEPTABLE CONTROL OF ALTITUDE COULD BE MAINTAINED IN THE EVENT OF ARTIFICIAL VERTICAL DAMPER FAILURE AS LONG AS THE CONTROL SYSTEM TIME CONSTANT REMAINED BELOW 0.37 SECOND. MINIMUM ACCEPTABLE CONTROL POWER WAS FOUND TO DEPEND ON THE VERTICAL VELOCITY RESPONSE DURING LIFT-OFF AND TOUCHDOWN MANEUVERS. HOVERING STEADINESS TEST WITH ZERO VELOCITY DAMPING INDICATED A TENDENCY TO OVER-CONTROL AT TIME CONSTANTS ABOVE 0.6 SECOND WHILE THE PILOT'S FULL ATTENTION WAS REQUIRED AT 1.2 SECONDS. THE RELATIVE IMPORTANCE OF COCKPIT MOTION AND VISUAL DISPLAY IN CORRELATING SIMULATOR AND FLIGHT DATA WAS BRIEFLY INVESTIGATED.

GERDES, R.M. AND WEICK, R.F. A PRELIMINARY PILOTED SIMULATOR AND FLIGHT STUDY OF HEIGHT CONTROL REQUIREMENTS FOR VTOL AIRCRAFT. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C., TECHNICAL NOTE D-1201, FEBRUARY 1962, 20 PP AD 272 130.

* ABSTRACT *

A FIXED-BASE PILOTED FLIGHT SIMULATOR WAS USED IN A PRELIMINARY INVESTIGATION OF REQUIREMENTS FOR VTOL AIRCRAFT ALTITUDE CONTROL. PILOT OPINION RATINGS WERE USED TO DETERMINE THE RELATIONSHIPS OF CONTROL SENSITIVITY, AND CONTROL POWER TO DAMPING FOR BOTH NORMAL FLIGHT AND SATISFACTORY CONTROL CHARACTERISTICS. CONTROL POWER SHOULD BE CAPABLE OF PRODUCING AT LEAST 1.2G UPWARD ACCELERATION FOR NORMAL FLIGHT AND AT LEAST 1.05 G FOR THE AUGMENTATION FAILURE FLIGHT CONDITION. A MINIMUM DAMPING LEVEL IS ABOUT -0.35 PER SECOND FOR NORMAL FLIGHT. FLIGHT RESULTS OBTAINED WITH THREE VTOL AIRCRAFT WERE IN REASONABLE AGREEMENT WITH THE SIMULATOR DATA. THE INFLUENCE OF CONTROL RESPONSE TIME CONSTANT AND GROUND EFFECT IN SHIFTING BASIC PILOT OPINION BOUNDARIES WAS ALSO INVESTIGATED ON THE SIMULATOR. CONTROL RESPONSE TIME CONSTANT RESTRICTS THE CONTROL BOUNDARIES, PARTICULARLY IN THE CASE WHERE HIGH CONTROL POWER AND LOW DAMPING LEVELS OR BOTH EXIST. INTRODUCTION OF POSITIVE GROUND EFFECT CHARACTERISTICS INTO THE HEIGHT-CONTROL SYSTEM RESULTED IN A MARKED IMPROVEMENT IN PILOT OPINION RATINGS. HOWEVER, IT WAS FOUND THAT ADDITIONAL DAMPING WAS REQUIRED TO COPE WITH THE OSCILLATORY HOVERING BEHAVIOR INDUCED AT LEVELS OF CONTROL POWER ABOVE 1.2 G. NEGATIVE GROUND EFFECT WAS RESPONSIBLE FOR A RAPID DETERIORATION IN HEIGHT CONTROLLABILITY; EXCESSIVE SINK RATES WERE DEVELOPED WHEN NEGATIVE GROUND EFFECT WAS COMBINED WITH LOW CONTROL POWER.

GIBBS, C.E. THE CONTINUOUS REGULATION OF SKILLED RESPONSE BY KINAESTHETIC FEEDBACK. 'BRITISH JOURNAL OF PSYCHOLOGY', VOL 45-46, 1954-55, PP 24-39.

* ABSTRACT *

NINETY FIVE NORMAL SUBJECTS AND ONE TABETIC PATIENT WERE TESTED IN EXPERIMENTS WHICH WERE DESIGNED TO ALTER SYSTEM-ATICALLY THE RESPONSE IN A VISUO-MOTOR SKILL AND THEREBY, TO ALTER THE PROPRIOCEPTIVE DISCHARGE IN THE CONTROLLING MUSCLES.

TWO TYPES OF JOYSTICK WERE USED TO CONTROL THE OUTPUT OF A VELOCITY CONTROL SERVO MECHANISM IN A TRACKING TASK. ONE LEVER WAS OF THE NORMAL FREE-MOVING TYPE, AND THERE THE MUSCULAR CONTRACTIONS WERE ISOTONIC WHEN THE SUBJECT WAS MAKING CONTROLLED RESPONSES BY DISPLACING THE LEVER. THE OTHER HAD STRONG SPRING CENTERING, BUT IT COULD BE DEFLECTED SLIGHTLY BY APPLYING PRESSURE, SO THAT THE CONTROLLED CONTRACTIONS OF MUSCLE WERE VIRTUALLY ISOMETRIC. CHANGES OF LIMB POSITION AND CHANGES IN THE FORCE EXERTED BY THE LIMB COULD THEREFORE BE COMPARED, USING THE CRITERIA OF SPEED AND ACCURACY.

ISOMETRIC CONTRACTION WITH THE PRESSURE CONTROL WAS DEFINITELY BETTER WHEN MAKING BOTH DISCRETE AND CONTINUOUS RESPONSES, LEARNING WAS EASIER AND DIFFERENTIAL TRANSFER EFFECTS APPEARED WHICH ALSO FAVOURED THE PRESSURE CONTROL. IT IS THOUGHT THAT THIS SUPERIORITY IS DUE TO THE MARKED DIFFERENCE IN THE PROPRIOCEPTIVE DISCHARGE IN THE TWO CONTRACTILE STATES. THE IMMEDIATE IMPLICATIONS ARE THAT SKILLED MOVEMENTS ARE CONTINUOUSLY REGULATED BY USING KINAESTHETIC DATA WHICH ARE GENERATED BY THE LIMB IN MOTION AND ARE CONTINUOUSLY FED BACK TO THE HIGHER MOTOR CENTERS. THE BROADER IMPLICATIONS ARE BRIEFLY DISCUSSED, ESPECIALLY HOW CAUSE AND EFFECT OPERATE IN SENSORY ORGANIZATION: A THEORY OF CONTROL IS THEREFORE DEVELOPED.

GIBBS, D.W. 'EFFECTS OF PRESENCE OR ABSENCE OF COCKPIT MOTION IN INSTRUMENT FLIGHT TRAINERS AND FLIGHT SIMULATORS'. TECHNICAL REPORT ASD-TR-68-24, JUNE, 1968.

* ABSTRACT *

THIS REPORT BRIEFLY EXAMINES THE EFFECT OF MOTION ON CREW MEMBERS IN TRAINING DEVICES WITH AND WITHOUT THE PRESENCE OF A MOTION SYSTEM. CONCLUSION OF MOTION SYSTEM RESEARCH ARE PRESENTED, INCLUDING A SAMPLE BIBLIOGRAPHY OF MOTION SYSTEM STUDIES AND PAPERS. THE REPORT CONCLUDES WITH RECOMMENDATIONS FOR PROCUREMENT PRACTICE AND OPERATIONAL USAGE.

GIBSON
PERFORMANCE RELATIONSHIPS OF A LINEAR SINGLE-DEGREE-OF-FREEDOM
FLIGHT SIMULATOR MOTION SYSTEM DURING A SHARP ONSET
ACCELERATION PROFILE.
'AERONAUTICAL SYSTEMS DIVISION'
WRIGHT-PATTERSON AFB, OH
REPT. ASD-TR-71-94, AD-752 222, MAR 1972.

* ABSTRACT *

THE REPORT EXAMINES A SHARP ACCELERATION PROFILE REPRESENTATIVE
OF THE CUEING MOTIONS PROVIDED TO CREW-MEMBERS IN FLIGHT
SIMULATORS. A LINEAR SINGLE-DEGREE-OF-FREEDOM MOTION IS
ASSUMED; THE RELATIONSHIPS AMONG DISPLACEMENT, VELOCITY LIMIT,
ACCELERATION ONSET, AND CUE DURATION ARE DETERMINED. DESIGN
IMPLICATIONS ARE INFERRED FROM THE RESULTS. (AUTHOR)

GIBSON, J.J. 'THE PERCEPTION OF THE VISUAL WORLD'. THE RIVER-
SIDE PRESS: CAMBRIDGE, MA, 1950.

* ABSTRACT *

THE PRINCIPAL SUBJECT OF THIS BOOK IS THE VISUAL PERCEPTION OF
SPACE. THE HYPOTHESES THE AUTHOR ADOPTED WERE PRECIPITATED BY
RESEARCH IN THE FIELD OF MILITARY AVIATION CARRIED OUT DURING
WORLD WAR II. CHAPTER 8, 'THE PROBLEM OF THE STABLE AND
BOUNDLESS VISUAL WORLD', DISCUSSES THE INTERACTION BETWEEN THE
VISUAL AND KINESTHETIC SENSES.

GIBSON, J.J. THE VISUAL PERCEPTION OF OBJECTIVE MOTION AND SUB-
JECTIVE MOVEMENT. 'PSYCHOLOGICAL REVIEW', 1954, 61, 304-314.

* ABSTRACT *

THE PERCEPTION OF MOTION IN THE VISUAL FIELD, WHEN RECOGNIZED
AS A PSYCHOLOGICAL PROBLEM INSTEAD OF SOMETHING SELF-EVIDENT,
IS OFTEN TAKEN TO PRESENT THE SAME KIND OF PROBLEM AS THE
PERCEPTION OF COLOR OR OF FORM. MOVEMENT IS THOUGHT TO BE
SIMPLY ONE OF THE CHARACTERISTICS OF AN OBJECT, AND THE ONLY
QUESTION IS HOW DO WE SEE IT. ACTUALLY, THE PROBLEM CUTS
ACROSS MANY OF THE UNANSWERED QUESTIONS OF PSYCHOLOGY,
INCLUDING THOSE CONCERNED WITH BEHAVIOR. IT INVOLVES AT LEAST
THREE SEPARABLE, BUT CLOSELY RELATED PROBLEMS: HOW DO WE SEE
THE MOTION OF AN OBJECT, HOW DO WE SEE THE STABILITY OF THE
ENVIRONMENT, HOW DO WE PERCEIVE OURSELVES AS MOVING IN A
STABLE ENVIRONMENT.

THE VARIOUS MOTIONS OF OBJECTS IN A STABLE ENVIRONMENT AND THE
VARIOUS MOVEMENTS OF OURSELVES IN THAT ENVIRONMENT CAN BOTH
BE VISUALLY PERCEIVED. A PSYCHOPHYSICS OF SUCH KINETIC

IMPRESSIONS, HOWEVER, IS ALMOST NONEXISTENT, AND THE POSSIBILITY OF ISOLATING THEIR STIMULI HAS BEEN DOUBTED. IF, HOWEVER, THE EFFECTIVE STIMULATION IS TAKEN TO BE ORDINAL AND RELATIONAL, IT FALLS INTO SEVERAL MATHEMATICAL CLASSES, WHICH ARE NEATLY CORRELATED WITH TYPES OF PHYSICAL EVENTS, AND WHICH MAY PROVE TO BE PSYCHOPHYSICALLY CORRELATED WITH MODES OF KINETIC EXPERIENCE.

VON GIERKE, H.E. AND STEINMETZ, E. 'MOTION DEVICES FOR LINEAR AND ANGULAR OSCILLATION AND FOR ABRUPT ACCELERATION STUDIES ON HUMAN SUBJECTS' (IMPACT). NATIONAL ACADEMY OF SCIENCES, NATIONAL RESEARCH COUNCIL, WASHINGTON DC, U.S.A. PUBLICATION 903, 1961.
SPECIAL REPORT FOR THE PANEL ON ACCELERATION STRESS. ARMED FORCES. NATIONAL RESEARCH COMMITTEE ON BIO-ASTRONAUTICS

* ABSTRACT *

THE AUTHORS DESCRIBE THE PURPOSES, DESIGN PRINCIPLES, MOTION CAPABILITIES, AND CONTROL AND SAFETY FEATURES OF ABOUT FORTY FACILITIES (INCLUDING MOTION SIMULATORS) DESIGNED TO STUDY THE EFFECTS OF LINEAR AND ANGULAR OSCILLATIONS AND OF ABRUPT ACCELERATION ON HUMAN SAFETY AND PERFORMANCE. PHOTOGRAPHS OR SCHEMATIC DRAWINGS OF THE DESIGN ARE PRESENTED FOR THOSE DEVICES FOR WHICH THEY ARE AVAILABLE.

GILLIES, J.A. (ED.) 'A TEXTBOOK OF AVIATION PHYSIOLOGY'. PERGAMON PRESS: LONDON, NEW YORK, 1965.

* ABSTRACT *

THIS IS A TEXTBOOK CONCERNING THE PRACTICE OF AVIATION MEDICINE AND AFFORDS A PICTURE OF THE PRINCIPLES PRACTICED AT THE R.A.F. INSTITUTE OF AVIATION MEDICINE. SECTION V ON 'ACCELERATIONS' COVERS THE PHYSIOLOGY OF ACCELERATION, THE EFFECTS OF ACCELERATIONS OF SHORT DURATION, AND MOTION SICKNESS. CHAPTER 29 INCLUDES SECTIONS ON VIBRATION IN FLIGHT SIMULATION AND THE EFFECTS OF VIBRATION ON MAN AND ANIMALS. CHAPTER 38 CONSIDERS THE EFFECTS OF ENVIRONMENTAL STRESS ON PERFORMANCE, AND CHAPTER 40 DEALS WITH 'SPATIAL DISORIENTATION' IN FLIGHT.

GILLINGHAM, K.K. SPATIAL DISORIENTATION HAS BEEN A DEADLY COMPROMISER OF PILOT PERFORMANCE EVER SINCE BLIND FLYING WAS FIRST ATTEMPTED. RESEARCH IN RECENT YEARS HAS LED TO A TRAINING DEVICE THAT A YEAR OR SO FROM NOW MAY ASSIST PILOTS IN OVERCOMING THIS THREAT. AEROSPACE SAFETY, JAN. 1967.

* ABSTRACT *

THE FIRST DEVICE FABRICATED FOR THE AIR FORCE TO DEMONSTRATE ILLUSIONS OF DISORIENTATION, THE SPATIAL DISORIENTATION DEMONSTRATION (SDD) WAS DESCRIBED. ALTHOUGH THE SDD DEMONSTRATED THAT SOME OF THE ILLUSIONS OF FLIGHT CAN BE REPRODUCED ON RELATIVELY INEXPENSIVE AND SAFE GROUND-BASED APPARATUS, IT WAS NOT CAPABLE OF SATISFYING EVALUATION AND TRAINING FUNCTIONS. THE SPATIAL ORIENTATION TRAINER (SOT) WAS DESIGNED TO SATISFY ALL OF THESE FUNCTIONS. THIS ARTICLE WENT ON TO DESCRIBE THE SOT. THE CORIOLIS AND OCULOGRAVIC ILLUSIONS WERE ALSO DESCRIBED IN THIS ARTICLE.

GILSON, R.D., GLEDY, F.E., JR., HIXSON, W.C. AND NIVEN, J.I. OBSERVATIONS ON PERCEIVED CHANGES IN AIRCRAFT ATTITUDE ATTENDING HEAD MOVEMENTS MADE IN A 2-G BANK AND TURN. 'AEROSPACE MEDICINE', VOL. 44, '1', JAN. 1973, 90-92.

* ABSTRACT *

BY USING A HIGH-SPEED AIRCRAFT AS A VERY LARGE RADIUS CENTRIFUGE, IT WAS POSSIBLE TO GENERATE A 2-G FORCE FIELD DURING A SUSTAINED BANK AND TURN WITH VERY LOW ANGULAR VELOCITY. THIS PERMITTED INVESTIGATION OF THE DYNAMIC EFFECTS OF HEAD MOVEMENTS ON PERCEIVED CHANGES IN AIRCRAFT ORIENTATION WHEN THE INERTIAL TORQUES FROM VESTIBULAR CORIOLIS CROSS-COUPLING EFFECTS WAS MINIMIZED. HEAD MOVEMENTS GENERATED LARGE MAGNITUDE SHIFTS IN APPARENT AIRCRAFT ORIENTATION IN A PLANE ORTHOGONAL TO THAT IN WHICH VESTIBULAR CORIOLIS CROSS-COUPLING EFFECTS OCCUR, WHICH SUGGESTS THAT THE SHIFTS WERE DUE TO AN OTOLITH G-EXCESS EFFECT. A LABORATORY CONTROL EXPERIMENT INDICATED THAT THE INFIGHT PERCEPTUAL PHENOMENA WERE NOT ATTRIBUTABLE TO THE INCREASED LOADS ON NECK MUSCLES DURING HEAD MOVEMENTS. INDIVIDUAL DIFFERENCES IN MAGNITUDES OF PERCEIVED ORIENTATION CHANGES ARE DISCUSSED.

GOLDMAN, C.F. AND VON GIERKE, H.E. THE EFFECTS OF SHOCK AND VIBRATION ON MAN, LECTURE AND REVIEW SERIES NO. 60-3, NAVAL MEDICAL RESEARCH INSTITUTE, BETHESDA, MARYLAND, JANUARY 1960.

* ABSTRACT *

IN RESPONSE TO NUMEROUS REQUESTS FROM INDUSTRY AND FROM GOVERNMENT AGENCIES FOR UNIFORM CRITERIA WITH WHICH TO EVALUATE AND ASSESS THE HAZARDS OF HUMAN VIBRATION EXPOSURE, THE AMERICAN NATIONAL STANDARDS SECTIONAL COMMITTEE ON BIO-Acoustics, S3, APPOINTED A COMMITTEE IN 1961 TO STUDY THE FEASIBILITY OF ESTABLISHING STANDARDS FOR THE EXPOSURE OF HUMAN BEINGS TO MECHANICAL VIBRATIONS. THE REPORT OF THIS COMMITTEE IN 1962 POINTED OUT THE LACK OF DEFINITIVE DATA WITH RESPECT TO MANY OF THE VARIABLES IN THIS PROBLEM AREA AND THAT

IT WILL BE IMPOSSIBLE TO PROVIDE ONE SIMPLE SET OF CRITERIA. IN SPITE OF THESE LIMITATIONS TO PRESENT KNOWLEDGE, THE COMMITTEE FELT THAT IN VIEW OF THE STATED NEED, A CAUTIOUS ATTEMPT TO DEVELOP SUCH CRITERIA IS JUSTIFIED. AS A CONSEQUENCE OF THESE RECOMMENDATIONS, EFFORTS ARE NOW UNDER WAY TO DEVELOP AN ADEQUATE STANDARD. ALTHOUGH IT IS ANTICIPATED THAT THE CRITERIA RESULTING WILL, OF NECESSITY, BE BROAD RATHER THAN SPECIFIC, THEY SHOULD BE OF DEFINITE ASSISTANCE IN AVOIDING PATENTLY EXCESSIVE VIBRATION EXPOSURES, IN JUDGING THE RELATIVE SEVERITY OF VIBRATION EXPOSURES FOR VARIOUS OCCUPATIONS AND CONDITIONS, AND IN COLLECTING NEW MATERIAL ON THIS SUBJECT.

SINCE THE DEVELOPMENT OF SUCH A STANDARD TAKES TIME, THE S3 COMMITTEE RECOMMENDED, AS AN INTERIM SOLUTION TO THE NUMEROUS REQUESTS FOR INFORMATION ON THIS SUBJECT, THE DISTRIBUTION BY ANSI OF THE FOLLOWING REPORT. THIS REVIEW OF THE EFFECTS OF SHOCK AND VIBRATION ON MAN COVERS A VERY BROAD SCOPE; VIBRATION EXPOSURE CRITERIA AS SUCH ARE DISCUSSED ONLY IN A SMALL PARAGRAPH IN IT. IT WAS FELT NEVERTHELESS THAT THE REMAINDER OF THE REPORT WOULD PROVIDE VALUABLE BACKGROUND INFORMATION FOR ANYONE INTERESTED IN THIS PROBLEM.

THE LAST FIVE YEARS HAVE BROUGHT CONSIDERABLE INTENSIFICATION OF HUMAN VIBRATION RESEARCH AND NOT ALL SECTIONS OF THE REPORT CAN BE CONSIDERED TO BE COMPLETELY UP-TO-DATE. HOWEVER, MOST OF THE RECENT RESEARCH HAS CONCENTRATED ON EXPOSURE TO EXTREME VIBRATION LEVELS AS THEY MAY OCCUR IN MILITARY ENVIRONMENTS AND IN SPACE MISSIONS. RELATIVELY LITTLE NEW WORK HAS BEEN PUBLISHED ON THE EFFECTS OF LONGTIME EXPOSURE TO MODERATE VIBRATION LEVELS, THE SITUATIONS OF MOST INTEREST WITH RESPECT TO THE INDUSTRIAL, HABITUAL VIBRATION EXPOSURES FOR WHICH STANDARDS ARE PRIMARILY DESIRABLE. THEREFORE, THE COMMITTEE RECOMMENDS DISSEMINATION OF THE FOLLOWING REPORT AS PERTINENT BACKGROUND AND REFERENCE MATERIAL ON HUMAN VIBRATION RESEARCH UNTIL SUCH TIME AS MORE DEFINITE GUIDANCE THROUGH A STANDARD ON PERMISSIBLE VIBRATION EXPOSURES CAN BE PROVIDED.

GOLDSMITH, C.T., SHERMAN, H. AND VITALE, P.A. RESEARCH ON THE SIMULATION REQUIREMENTS OF AEROSPACE VEHICLE MOTION CHARACTERISTICS IN GROUND TRAINING SYSTEMS. GRUMMAN AIRCRAFT ENGINEERING CORPORATION, PROJECT 1710 TASK 171003, 1961.

* ABSTRACT *

SEVEN SUBJECTS IN SIMULATION OF TERRAIN CLEARANCE TASKS. SIMULATED TURBULENCE (BASED ON 2 GUST VELOCITY VALUES) ADDED TO AIRCRAFT MOTION LED TO POORER PERFORMANCE THAN AIRCRAFT MOTION SIMULATION ALONE (PITCH, ROLL AND HEAVE ACCELERATIONS). STATIC COCKPIT SIMULATION APPEARED TO GIVE RISE TO SLOWER LEARNING OF THE TASK.

GBLTRA, E.R. AND HYDE, A.S. THE DYNAMIC ESCAPE SIMULATOR.
AIAA/AFSC/ASD 'SUPPORT FOR MANNED FLIGHT CONFERENCE', AIAA PAPER
65-278, DAYTON, OHIO, APRIL 21-23, 1965.

* ABSTRACT *

WITH INCREASING COMPLEXITY OF PRESENT AND FUTURE AEROSPACE SYSTEMS IN INCREASING NEED HAS BEEN MANIFEST FOR GROUND SIMULATION OF MISSION ENVIRONMENTS. THE UNKNOWN INTERACTIONS OF MULTIPLE, CONCURRENT STRESSES, THE AS YET UNDEFINED EFFECTS OF SEQUENTIAL STRESSES AND THE FUNDAMENTAL NEED OF TRAINING, WHICH REQUIRES REPEATED EXPOSURE TO THE MISSION ENVIRONMENTS, ALL DEMAND THAT A CENTRIFUGE DESIGNED FOR TRAINING AND BASIC RESEARCH SHOULD BE CAPABLE OF PROVIDING THE VIBRATION, GAS COMPOSITIONS, PRESSURES, AND ACOUSTIC AND THERMAL VARIABLES WHICH MAY OCCUR IN AN AEROSPACE VEHICLE DURING NORMAL FLIGHT OR DURING AN EMERGENCY. THIS PRESENTATION CONSIDERS THE THEORETICAL OPTIMAL DESIGN, THE DESIGN WHICH IS PRACTICAL WITHIN ECONOMIC LIMITS AND FACILITY CONSTRAINTS, THE SPECIFICATIONS OF A FEASIBLE DEVICE OF THIS TYPE, THE DYNAMIC ESCAPE SIMULATOR AT THE AEROSPACE MEDICAL RESEARCH LABORATORIES NOW IN FINAL CONSTRUCTION, AND THE TRADE-OFFS NECESSARY TO ACHIEVE THIS DIRECTLY NEEDED RESEARCH INSTRUMENT.

VAN GIBL, M.F.C., INFLUENCE OF MOTION WASH-OUT FILTERS ON PILOT TRACKING PERFORMANCE
NATIONAL AEROSPACE LABORATORY NLR
ANTHONY FOKKERWEG 2
1059 CM AMSTERDAM
THE NETHERLANDS
PRESENTED AT AGARD MEETING ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS, BELGIUM, 24-27 APRIL 1978.

* ABSTRACT *

AN INVESTIGATION HAS BEEN CARRIED OUT ON THE NLR MOVING BASE FLIGHT SIMULATOR TO ESTABLISH THE INFLUENCE OF THE SIMULATOR MOTION WASH-OUT FILTERS IN THE PITCH AND ROLL AXIS ON THE PERFORMANCE OF FOUR PILOTS WHEN STABILIZING AN AIRCRAFT DISTURBED BY TURBULENCE IN EITHER OF THESE AXES. FOR THIS COMPENSATORY TRACKING TASK, PILOT DESCRIBING FUNCTIONS, REMNANT SPECTRA AND OTHER PERFORMANCE MEASURES HAVE BEEN DETERMINED.

THE RESULTS LEAD TO THE CONCLUSION THAT, FOR THE TASK UNDER CONSIDERATION, NO SIGNIFICANT DIFFERENCES CAN BE OBSERVED WHEN THE BREAK FREQUENCY OF THE (LINEAR SECOND-ORDER) WASH-OUT FILTER IS VARIED FROM 0.1 RAD/SEC TO 0.5 RAD/SEC. HOWEVER, PERFORMANCE IN EITHER CONDITION IS CONSIDERABLY BETTER WHEN COMPARED TO FIXED-BASE RESULTS. THIS IS ALSO REFLECTED IN THE PILOT

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COMMENTS AND EFFORT RATINGS, STATING THAT THE TASK IS EASIER WITH MOTION.

GOTTSDANKER, R. REACTION TIME: THE TIME TO INITIATE A RESPONSE. MINNEAPOLIS-HONEYWELL, AERO-DOCUMENT U-ED 6102, 31 DECEMBER, 1958.

* ABSTRACT *

BRIEF REVIEW ARTICLE CONCERNING HUMAN REACTION TIME AND ITS RELATIONSHIP TO THE FOLLOWING VARIABLES:

1. STRENGTH OF VARIABLES
 - A. INTENSITY OF SIGNAL
 - B. DISCRIMINABILITY
 - C. MOTIVATION
 - D. PREPARATION
 - E. PRACTICE
2. MINIMUM RT AND COMPARISON OF SENSES.
3. COMPLEXITY CONDITIONS
4. RELATION TO OTHER ASPECTS OF BEHAVIOR.
 - A. ASSOCIATION TIME
 - B. OPERANT CONDITIONING
 - C. TRACKING
5. INSTRUMENTATION
 - A. SIGNALS
 - B. RESPONSES
 - C. RECORDING
6. SPECIAL CONDITIONS SUCH AS DRIVING A CAR.

GRAHAM, D.K. A RATIONALE FOR MOVING-BASE FLIGHT SIMULATION AND A PRELIMINARY STATEMENT OF THE MOTION REQUIREMENTS. THE BEEING COMPANY DOCUMENT NO. D6-57149, AUGUST 1968.

* ABSTRACT *

A RATIONALE SUPPORTING THE NEED FOR MOVING-BASE FLIGHT SIMULATION IN SYSTEM RESEARCH AND DEVELOPMENT IS PRESENTED. THIS INFORMATION IS BASED ON AN EXTENSIVE SURVEY AND ANALYSIS OF THE PERTINENT EXPERIMENTAL LITERATURE. THE STUDY CONCLUDES THAT MOVING-BASE SIMULATION IS REQUIRED AND AT LEAST FOUR DEGREES OF FREEDOM PITCH, ROLL, VERTICAL TRANSLATION, AND LATERAL TRANSLATION BE PROVIDED. THIS DOCUMENT ALSO PRESENTS PRELIMINARY MOTION SPECIFICATIONS FOR THE FOUR AXIS INDICATED.

GRAVES, G.B., JR. FLIGHT SIMULATION TECHNOLOGY - SIMULATION TECHNIQUES, NASA LANGLEY 73w70056, 1973

* ABSTRACT *

COMPUTER BASED FLIGHT SIMULATION STUDIES PERMEATE ALL PHASES OF AEROSPACE TECHNOLOGY DEVELOPMENT, FROM CONCEPTUAL DESIGN THROUGH PILOT TRAINING. THE ALLIANCE OF FLEXIBLE SIMULATOR HARDWARE WITH HIGH-SPEED COMPUTING EQUIPMENT REPRESENTS A RESEARCH APPROACH TO PROBLEMS THAT COULD NOT OTHERWISE BE PRACTICALLY SOLVED. THE OBJECTIVE OF THE WORK UNDER THIS RTOP IS TO PROVIDE SUBSTANTIAL IMPROVEMENT IN NASA'S CAPABILITY FOR FLIGHT SIMULATION THROUGH THE INTEGRATION OF THE SPECIALIZED SIMULATION ASPECTS OF COMPUTER SCIENCE, APPLIED MATHEMATICS, OPTICS, AND SERVOMECHANISMS. EMPHASIS WILL BE PLACED ON COMPUTER TECHNIQUES FOR VISUAL SCENE GENERATION TO REMOVE THE FIELD OF VIEW RESTRICTIONS WHICH ENCUMBER PRESENT SYSTEMS. EFFORT WILL BE UNDERTAKEN ON ADVANCED MATHEMATICAL AND COMPUTING TECHNIQUES TO PERMIT A HIGH DEGREE OF SIMULATION FIDELITY WITHIN REASONABLE COMPUTER MEMORY AND SPEED LIMITATIONS. THIS ALSO INCLUDES WORK ON OPTIMAL STRATEGIES TO HANDLE THE ONSET AND WASHOUT CUES TO SIMULATE FLIGHT MOTIONS WITHIN THE LIMITED DISPLACEMENTS WHICH ARE PRACTICAL FOR GROUND SIMULATORS. DEVELOPMENT AND PROCUREMENT WILL BE UNDERTAKEN ON SPECIALIZED SYSTEMS WHICH ARE CAPABLE OF PROVIDING GENERAL SUPPORT TO A BROAD SPECTRUM OF AERONAUTICAL RESEARCH PROGRAMS WHERE IT HAS NOT BEEN PRACTICAL TO SUPPORT THESE EFFORTS BY INDIVIDUAL PROGRAM FUNDING.

GRAY, T.H. AND FULLER, R.R. SIMULATOR TRAINING AND PLATFORM MOTION IN AIR-TO-SURFACE WEAPON DELIVERY TRAINING. FLYING TRAINING DIVISION AIR FORCE HUMAN RESOURCES LABORATORY, WILLIAMS AFB, ARIZONA. PAPER SUBMITTED TO '1977 NTEC/INDUSTRY CONFERENCE'. (ALSO PUBLISHED AS AIR FORCE HUMAN RESOURCES LABORATORY REPORT AFHRL-TR-77-29, JULY, 1977.)

* ABSTRACT *

THE OBJECTIVES OF THIS RESEARCH WERE TO DETERMINE: (1) THE EXTENT TO WHICH GENERALIZED, CONVENTIONAL, AIR TO SURFACE (A/S) WEAPONS DELIVERY TRAINING IN THE ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT) TRANSFERRED TO A SPECIFIC AIRCRAFT; (2) THE CONTRIBUTION OF SIX DEGREE OF FREEDOM PLATFORM MOTION TO THE TRANSFER OF TRAINING FROM SIMULATOR TO AIRCRAFT; AND (3) THE DIFFERENTIAL EFFECTS, IF ANY, OF THIS SIMULATOR TRAINING ON STUDENT PILOTS OF DIFFERENT ABILITY LEVELS. THESE OBJECTIVES WERE ACCOMPLISHED BY SELECTING 24 STUDENTS IN THE LEAD-IN A/S TRAINING COURSE AT HOLLAMAN AFB TO SERVE AS SUBJECTS. THESE SUBJECTS PROGRESSED THROUGH LEAD-IN TRAINING, RECEIVING ALL TRAINING EXCEPT THE A/S FLIGHTS, AND THEN PROCEEDED TO WILLIAMS AFB WHERE THEY WERE ASSIGNED INTO MATCHED EXPERIMENTAL AND CONTROL GROUPS. AT WILLIAMS AFB, ALL OF THE SUBJECTS RECEIVED ACADEMIC TRAINING IN WEAPONS DELIVERY TECHNIQUES AND PROCEDURAL TRAINING ON F-5B OPERATIONS. AT THIS POINT, THE STUDENTS IN THE CONTROL GROUP FLEW TWO DATA COLLECTION SORTIES IN THE F-5B AIRCRAFT, PERFORMING 10 DEGREE, 15 DEGREE, AND 30 DEGREE BOMB

DELIVERIES. THE EXPERIMENTAL GROUPS RECEIVED A/S WEAPONS DELIVERY TRAINING IN ASPT ON 10 DEGREE, 15 DEGREE AND 30 DEGREE BOMB DELIVERIES WITH A FIXED NUMBER OF TRIALS ON EACH EVENT. THE EXPERIMENTAL SUBJECTS THEN RECEIVED TWO DATA COLLECTION FLIGHTS IN THE F-5B IDENTICAL TO THOSE RECEIVED BY THE CONTROL GROUP. ANALYSIS OF THE RESULTS PROVED THAT SIMULATOR TRAINING SIGNIFICANTLY INCREASED AIR-TO-SURFACE WEAPONS DELIVERY SKILLS (E. G., APPROXIMATELY DOUBLE THE NUMBER OF QUALIFYING BOMBS, A ONE-FOURTH REDUCTION IN CIRCULAR ERROR) BUT THAT PLATFORM MOTION WAS NOT A CONTRIBUTING FACTOR IN THIS PROCESS. IT WAS ALSO FOUND THAT NOVICE STUDENT PILOTS OF GREATER INITIAL ABILITY BENEFIT MOST FROM SUCH SIMULATOR TRAINING WHEN A MINIMUM FIXED NUMBER OF TRIALS IS USED.

GRAYBIEL, A. AND CLARK, B. DURATION OF OCULOGYRAL ILLUSION AS A FUNCTION OF THE INTERVAL BETWEEN ANGULAR ACCELERATION AND DECELERATION. ITS SIGNIFICANCE IN TERMS OF DYNAMICS OF SEMICIRCULAR CANALS IN MAN. JOURNAL OF APPLIED PSYCHOLOGY, VOL 5 NO. 4 PP. 147-152. OCTOBER 1952.

* ABSTRACT *

IF A PERSON IS ROTATED IN THE DARK WHILE OBSERVING A LUMINOUS OBJECT STATIONARY WITH RESPECT TO HIMSELF, THE OBJECT WILL APPEAR TO MOVE IN RELATION TO THE ONSET AND CESSATION OF ROTATION. THIS HAS BEEN TERMED THE OCULOGYRAL ILLUSION AND IT HAS BEEN SHOWN TO BE A RELIABLE INDICATOR OF CERTAIN REFLEX EFFECTS OF SIMULATION OF THE SEMICIRCULAR CANALS. BY VARYING THE PERIOD BETWEEN THE ONSET AND CESSATION OF ROTATION IT WAS POSSIBLE TO STUDY THE INHIBITORY EFFECT OF A STIMULUS DUE TO POSITIVE ANGULAR ACCELERATION ON A SUCCEEDING STIMULUS OF OPPOSITE SIGN. DATA WERE OBTAINED ON SIX SUBJECTS AND THE DURATION OF THE OCULOGYRAL ILLUSION WAS PLOTTED AGAINST THE INTERVAL BETWEEN ACCELERATION AND DECELERATION. THE POINTS DEFINED A CURVE WHICH CLEARLY INDICATED THE RECOVERY PATTERN. AN INITIAL STEEP RISE WAS FOLLOWED BY A GRADUAL AND CONTINUOUS ASCENT TOWARD A PLATEAU. IT INDICATED THAT RECOVERY WAS AT FIRST VERY RAPID THEN PROGRESSIVELY SLOWER BUT WITHOUT OVERSHOOT. THIS TYPE OF RECOVERY PATTERN IS UNLIKE THAT ENCOUNTERED IN MECHANICAL SYSTEMS BUT IS CHARACTERISTIC OF CERTAIN BIOLOGICAL SYSTEMS. EXPRESSED IN TERMS OF CUPULAR ENDOLYMPH BEHAVIOR OUR RESULTS SUGGEST A CHANGING RATIO OF VISCOUS TO ELASTIC FORCES AS THE CUPULA MOVES TOWARD OR AWAY FROM THE NEUTRAL POSITION. OUR FINDINGS ARE NOT IN ACCORD WITH THE CURRENT CONCEPT THAT THE CUPULA BEHAVES AS A HIGHLY DAMPED TORSION PENDULUM BUT RATHER AS A CRITICALLY DAMPED ELASTIC STRUCTURE. THESE DATA ILLUSTRATE A FACTOR WHICH TENDS TO KEEP THE AFTEREFFECTS OF STIMULATION OF THE SEMICIRCULAR CANALS SMALL IN EVERYDAY LIFE. HOWEVER, DURING AND FOLLOWING PROLONGED TURNS IN AIRCRAFT AT NIGHT WHEN THESE FACTORS DO NOT OPERATE SPATIAL ORIENTATION MAY BE IMPAIRED.

GRAYBIEL, A. AND KNEPTON, J. PREVENTION OF MOTION SICKNESS IN FLIGHT MANEUVERS, AIDED BY TRANSFER OF ADAPTATION EFFECTS ACQUIRED IN THE LABORATORY: TEN CONSECUTIVE REFERRALS. AVIAT. SPACE ENVIRON. MED. 49(7):914-919, 1978.

* ABSTRACT *

TEN FLYERS, GROUNDED BECAUSE OF NAUSEA AND VOMITING, WERE REFERRED AS POTENTIAL CANDIDATES FOR ADAPTATION TO CROSS-COUPLED ANGULAR ACCELERATIONS IN A SLOW-ROTATION ROOM; SUCH ADAPTATION HAS BEEN SHOWN TO TRANSFER TO FLIGHT MANEUVERS. THERE WAS NO OPPORTUNITY TO ATTEMPT TREATMENT IN TWO CANDIDATES. AMONG THE REMAINING EIGHT, FIVE REGAINED FLIGHT STATUS (62.5%); FOLLOW-UP PERIODS OF THOSE FIVE CANDIDATES RANGED FROM 10 TO 27 MONTHS. IN ONE OF THE THREE REMAINING CANDIDATES, A SATISFACTORY LEVEL OF ADAPTATION WAS ACHIEVED BUT MORE THAN 4 MONTHS ELAPSED BEFORE HIS ASSIGNMENT TO A DUTY SQUADRON. AFTER BECOMING SICK IN HIS FIRST FLIGHT (F-104), HE SUBMITTED A REQUEST TO BE REMOVED FROM DUTY INVOLVING FLYING. IN THE REMAINING TWO CANDIDATES, THE RATE OF THEIR ACQUISITION OF ADAPTATION NOT ONLY WAS VERY SLOW BUT ALSO, AFTER LEVELING OFF, ACTUALLY DECLINED. IN OTHER WORDS, POOR AS WELL AS GOOD PERFORMANCE IS DEMONSTRABLE IN THE SLOW-ROTATION ROOM.

GRAYBIEL, ASHTON, NIVEN, J.I. AND MACCORQUODALE, K. THE EFFECT OF LINEAR ACCELERATION ON THE OCULOGYRAL ILLUSION. USN SCHOOL OF AVIATION MEDICINE RESEARCH REPORT, 1956, NM 001-110-100 REPORT NO. 42, 1-16.

* ABSTRACT *

AGREEMENT IS LACKING CONCERNING THE EFFECTS OF LINEAR ACCELERATION ON THE SENSORY RECEPTORS IN THE SEMICIRCULAR CANALS. A LIMITED EXPERIMENTAL APPROACH TO THIS PROBLEM WAS UNDERTAKEN, MAKING USE OF THE FACT THAT A PERSON CAN BE SUBJECTED SIMULTANEOUSLY TO ANGULAR AND LINEAR ACCELERATIONS ON A HUMAN CENTRIFUGE. THE PATTERNS OF ANGULAR ACCELERATION, THE PHYSIOLOGICAL STIMULUS TO THE SEMICIRCULAR CANALS, WERE KEPT CONSTANT; THOSE OF LINEAR ACCELERATION WERE VARIED BY HAVING THE SUBJECT SIT EITHER NEAR THE CENTER OF ROTATION OR 17 FEET AWAY. THE DURATION OF THE OCULOGYRAL ILLUSION WAS USED AS AN INDICATION OF STIMULATION OF THE SEMICIRCULAR CANALS.

THE RESULTS OF THIS STUDY SHOW THAT THE DURATION OF THE OCULOGYRAL ILLUSION IS AN INCREASING FUNCTION OF INCREASING ANGULAR ACCELERATION. THE HEADING OF THE OBSERVER RELATIVE TO THE AXIS OF ROTATION OF THE CENTRIFUGE DOES NOT AFFECT THE DURATION OF THE OCULOGYRAL ILLUSION. THE INCREASED MAGNITUDE OF THE LINEAR ACCELERATION COMPONENT EXPERIENCED WHEN THE SEATING RADIUS IS INCREASED FROM 2 TO 17 FEET DOES NOT AFFECT

THE DURATION, UP TO CENTRIFUGE SPEEDS OF 8 RPM (MAXIMUM ANGLE C EQUALS 20 DEGREES). THE INCREASE IN MAGNITUDE OF THE LINEAR ACCELERATION COMPONENT WITH INCREASE IN CENTRIFUGE SPEED BEYOND THIS ANGLE BECOMES INCREASINGLY DISRUPTIVE OF PERFORMANCE, AS OCULOGRAVIC EFFECTS BECOME DOMINANT. THE SIGN OF ACCELERATION, I. E., POSITIVE AND NEGATIVE ACCELERATION, MOST PROBABLY DOES NOT INFLUENCE THE DURATION.

GUECRY, F.E., JR.
VISUAL COUNTERACTION OF NAUSEOGENIC AND DISORIENTING EFFECTS OF SOME WHOLE-BODY MOTIONS - A PROPOSED MECHANISM. NAMRL-1232.
PENSACOLA, FL: NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY,
16 FEBRUARY 1977.

* ABSTRACT *

IT HAS BEEN INDICATED THAT THE NAUSEOGENIC AND DISORIENTING EFFECTS OF SEVERAL KINDS OF PROVOCATIVE MOTION STIMULI CAN BE AMELIORATED BY VISUAL REFERENCE TO THE EARTH. THE PURPOSE OF THE PRESENT EXPERIMENT IS TO INVESTIGATE A HYPOTHESIS CONCERNING THE MECHANISM OF THIS BENEFICIAL EFFECT.

THE RESULTS DEMONSTRATE THAT THE AFTEREFFECTS OF LARGE-FIELD OPTOKINETIC STIMULATION CAN NULLIFY THE NAUSEOGENIC AND DISORIENTING EFFECTS OF CORIOLIS CROSS-COUPLED VESTIBULAR STIMULI. IT IS HYPOTHESIZED THAT LARGE-FIELD OPTOKINETIC STIMULATION IN A PARTICULAR HEAD PLANE MODIFIES ACTIVITY IN THE VESTIBULAR NUCLEI AS THOUGH THE SEMICIRCULAR CANALS IN THAT PLANE HAD BEEN STIMULATED. A PREVIOUS STUDY ILLUSTRATED THAT SUCH SEMICIRCULAR CANAL STIMULATION WOULD COMPLETELY NULLIFY THE DISTURBING AND DISORIENTING EFFECTS OF CORIOLIS CROSS-COUPLED STIMULATION ACCORDING TO THEORETICAL EXPECTATIONS. THE RESULTS PROVIDE INFERENTIAL SUPPORT FOR THE HYPOTHESIS AND SUGGEST THAT PREDICTABILITY OF DISORIENTATION AND NAUSEOGENIC DISTURBANCE ARE REASONABLY WELL HANDLED BY CURRENT THEORY WHEN THE CONDITIONS OF MOTION ARE FAIRLY WELL SPECIFIED.

GUECRY, F.E., JR., A.J. BENSON
CORIOLIS CROSS-COUPLING EFFECTS: DISORIENTING AND NAUSEOGENIC OR NOT; NAMRL-1231. PENSACOLA, FL: NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY, 20 DECEMBER 1976.

* ABSTRACT *

NAUSEA, VOMITING, AND DISORIENTATION ARE SOMETIMES PRODUCED BY HEAD MOVEMENTS DURING TURNING MANEUVERS IN AIRCRAFT. THESE RESPONSES ARE USUALLY ATTRIBUTED TO CORIOLIS CROSS-COUPLING STIMULATION OF THE VESTIBULAR SYSTEM, ALTHOUGH IT HAS BEEN INDICATED RECENTLY THAT MANY TURNING MANEUVERS OF AIRCRAFT HAVE INSUFFICIENT ANGULAR VELOCITY TO GENERATE SUCH EFFECTS. THE

PURPOSE OF THE STUDY WAS TO FURTHER DISTINGUISH CONDITIONS IN WHICH CORIOLIS CROSS-COUPPLING EFFECTS ARE DISORIENTING AND NAUSEOGENIC FROM CONDITIONS IN WHICH THEY ARE NEITHER DISORIENTING NOR NAUSEOGENIC.

WHEN HEAD TILTS ARE EXECUTED DURING AN ANGULAR ACCELERATION WHICH COMMENCES A TURN, VESTIBULAR STIMULATION IS NEITHER DISORIENTING NOR NAUSEOGENIC. DURING CONSTANT SPEED TURNS AND DURING DECELERATION WHICH STOPS SUCH TURNS, CORIOLIS CROSS-COUPPLING EFFECTS CAN BE DISORIENTING AND NAUSEOGENIC IF THE ANGULAR VELOCITY OF THE TURNING VEHICLE IS OF SUFFICIENT MAGNITUDE AT THE TIME THE HEAD MOVEMENT IS MADE.

GLEDY, F.E. JR., GILSON, R.D. AND STOCKWELL, C.W. SUBJECTIVE AND NYSTAGMUS REACTIONS CONSIDERED IN RELATION TO MODELS OF VESTIBULAR FUNCTION. FIFTH SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE EXPLORATION, HELD AT THE NAVAL AEROSPACE MEDICAL RESEARCH LAB., PENSACOLA, FL., AUG 19-21, 1970. PUBLISHED AS NASA SP-314, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., D.C., 1973.

* ABSTRACT *

MODELLING WILL BECOME INCREASINGLY IMPORTANT AS MORE KNOWLEDGE IS ACCUMULATED, BECAUSE IT OFFERS ADVANTAGES IN PREDICTING REACTIONS OF INDIVIDUALS IN A VARIETY OF SITUATIONS, INCLUDING NAVAL AEROSPACE ENVIRONMENTS, AND IN SPECIFYING A FEW PARAMETERS WHICH SHOULD HAVE CONSIDERABLE CLINICAL SIGNIFICANCE. HOWEVER, THE NEED FOR CONTINUING EXPERIMENTAL (CROSSCHECKS) OF THESE MODELS HAS BEEN ILLUSTRATED BY SEVERAL SETS OF RESULTS WHICH WOULD NOT HAVE BEEN PREDICTED BY ANY EXISTING MODELS.

GLEDY, F.E. JR. AND GRAYBIEL, A. ROTATION DEVICES, OTHER THAN CENTRIFUGES AND MOTION SIMULATORS. ARMED FORCES-NATIONAL RESEARCH COUNCIL ON BIO-ASTRONAUTICS, NATIONAL ACADEMY OF SCIENCES NATIONAL RESEARCH COUNCIL, WASHINGTON, D.C. PUBLICATION 902, 1961, 40 PP, AD 262 435.

* ABSTRACT *

THIS REPORT DEALS WITH ROTATION DEVICES USED IN STUDYING THE ROLE OF THE SEMICIRCULAR CANALS AND OTOLITH ORGANS IN AEROSPACE FLIGHT. MOST OF THESE DEVICES HAVE LIMITED CAPABILITY AS FLIGHT SIMULATORS BUT ARE INSTRUMENTED FOR CONTROLLING AND RECORDING THE DYNAMIC PERFORMANCE OF THE ROTARY STRUCTURE AND FOR MEASURING ELECTROPHYSIOLOGICAL AND BEHAVIORAL RESPONSES OF THE SUBJECTS. THE GREATER NUMBER ARE TO STIMULATE THE SEMICIRCULAR CANALS, ORGANS UNIQUELY STRUCTURED TO RESPOND TO ANGULAR ACCELERATIONS. THE OTOLITH ORGANS, WHICH ARE STIMULATED BY LINEAR ACCELERATIONS, RESPOND TO CHANGE IN BODY

(HEAD) POSITION WITH RESPECT TO THE DIRECTION OF GRAVITY OR ANY INERTIAL FORCE OF SUFFICIENT MAGNITUDE. BRIEF DESCRIPTIONS OF THESE ROTATION DEVICES AND WHERE THEY ARE LOCATED ARE GIVEN IN THE REPORT.

GUERCIO, J.G. AND WALL, R.L. CONGRUENT AND SPURIOUS MOTION IN THE LEARNING AND PERFORMANCE OF A COMPENSATORY TRACKING TASK DEPARTMENT OF PSYCHOLOGY, SAN JOSE STATE COLLEGE, SAN JOSE, CALIFORNIA, HUMAN FACTORS, 1972, 14(3), 259-269.

* ABSTRACT *

THE IMPORTANCE OF CONGRUENT AND SPURIOUS YAW MOTION IN COMPENSATORY TRACKING BY EIGHT AIRPLANE PILOTS WAS EXAMINED. THE PILOTS, SEATED ERECT IN THE AMES MAN-CARRYING ROTATION DEVICE (MCRD), TRACKED WITH $K/S+1$ AND $K/S(S+1)$ VEHICLE DYNAMICS IN FIXED AND MOVING-BASE SIMULATION. FOLLOWING THE LEARNING PHASE OF THE EXPERIMENT, FIVE LEVELS OF SPURIOUS ANGULAR ACCELERATION WERE SUPERIMPOSED ON THE MOTION OF THE MCRD. LEARNING OF THE TRACKING TASK WAS FOUND TO BE A FUNCTION OF BOTH VEHICLE DYNAMICS AND MODE OF SIMULATION. THE PRESENCE OF CONGRUENT MOTION INFORMATION REDUCED LEARNING TIME IN $K/S(S+1)$ VEHICLE DYNAMICS AND RESULTED IN LOWER TRACKING ERROR IN BOTH VEHICLE DYNAMICS. THE SPURIOUS ANGULAR ACCELERATION RESULTED IN LOWER TRACKING ERROR; HOWEVER, THE RELATIONSHIP BETWEEN THE MAGNITUDE OF THE ACCELERATION AND ITS EFFECT WAS HIGHLY COMPLEX. THE DATA SUGGEST THAT THE MINIMAL DISTURBANCE LEVEL FOR SPURIOUS ANGULAR ACCELERATIONS DURING TRACKING IS BELOW 0.4 DEGREES/SEC. SQUARED.

GUY, D.R. MODELING OF THE HUMAN FORCE AND MOTION-SENSING MECHANISMS, AIR FORCE HUMAN RESOURCES LAB, BROOKS AIR FORCE BASE TEXAS. REPORT NO. AFHRL - TR - 72 - 54 JUNE 1973, AD 766-444.

* ABSTRACT *

THE PURPOSE OF THE STUDY WAS TO INVESTIGATE HUMAN FORCE AND MOTION-SENSING MECHANISMS, TO DEVELOP MODELS OF THE PROMINENT OR POTENTIALLY ARTIFICIALLY STIMULATABLE MECHANISMS, TO IMPLEMENT THEM ON AN ANALOG COMPUTER, AND TO INVESTIGATE THEIR RESPONSES TO VARIOUS FORCE AND MOTION-FORCING FUNCTIONS. MODELS WERE IMPLEMENTED AND TESTED FOR A SEMICIRCULAR CANAL, THE OTOLITH, HEAD MOTION MUSCLE SPINDLE SENSING, AND BODY SEAT PRESSURE SENSING. TESTS OF THE MODELS HAVE DEMONSTRATED THE RELATIVE TIME DELAYS BETWEEN APPLIED FORCE AND PERCEIVED FORCE FOR THE VARIOUS MECHANISMS, SHOWING THAT BOTH THE MUSCLE SPINDLE AND PRESSURE SENSING MECHANISMS PERCEIVE AN APPLIED FORCE MUCH MORE RAPIDLY THAN THE VESTIBULAR SYSTEM. ALSO, THE LONG ADAPTATION PHENOMENON ASSOCIATED WITH THE SEMICIRCULAR CANALS WHICH SEEMS TO DEGRADE THEIR USEFULNESS IN FLIGHT AND THE RAPID ADAPTATION PHENOMENA ASSOCIATED WITH THE PRESSURE

SENSORS WHICH MAKES THEM IMPORTANT SENSORS FOR CONSIDERATION IN THE DESIGN OF MOTION SYSTEMS HAVE BEEN SHOWN THROUGH MODEL TESTING.

GLM, D.R. AND ALBERY, W.B.
INTEGRATION OF AN ADVANCED CIG VISUAL AND SIMULATOR SYSTEM.
(USAF, ADVANCED SYSTEMS DIVISION, WRIGHT-PATTERSON AFB, OHIO).
IN VISUAL AND MOTION SIMULATION CONFERENCE, DAYTON, OHIO, APRIL
26-28, 1976, PROCEEDINGS (A76-29476 13-53) NEW YORK, AMERICAN
INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, INC. 1976 P. 32-38.

* ABSTRACT *

AN ADVANCED COMPUTER IMAGE GENERATION (CIG) VISUAL SYSTEM HAS BEEN INTEGRATED WITH AN ADVANCED FLIGHT TRAINING SIMULATOR. THIS EFFORT ENCOUNTERED SOME NEW AND UNIQUE PROBLEMS OF VISUAL AND MOTION SYSTEM TIME DELAYS AND CUE COORDINATION. A SYNCHRONOUS VISUAL/SIMULATOR INTEGRATION METHOD WAS EMPLOYED WITH THE CIG SYSTEM SERVING AS THE MASTER CLOCK FOR THE TOTAL SIMULATION SYSTEM. THE INTEGRATION SOFTWARE USED A TECHNIQUE CALLED SINGLE INTERNAL LEAD TO COMPENSATE FOR THE MAJORITY OF THE TRANSPORT DELAY INHERENT IN CIG VISUAL SYSTEMS. THE INTEGRATION SCHEME AND THE IMPACT OF ITERATION RATES, HARDWARE DELAYS, AND DELAY COMPENSATION ON VISUAL AND MOTION CUE COORDINATION AS PERCEIVED BY PILOTS ARE PRESENTED.

GLM, D. R., AND ALBERY, W. B.
TIME DELAY PROBLEMS ENCOUNTERED IN INTEGRATING THE ADVANCED
SIMULATOR FOR UNDERGRADUATE PILOT TRAINING.
'U. AIRCRAFT'
VOL. 14, NO. 4, APR. 1977.

* ABSTRACT *

AN ADVANCED COMPUTER IMAGE GENERATION (CIG) VISUAL SYSTEM HAS BEEN INTEGRATED WITH AN ADVANCED FLIGHT TRAINING RESEARCH SIMULATOR. THE INTEGRATION DESIGN WAS THE FIRST DEVELOPED FOR INTEGRATING A CIG VISUAL SYSTEM WITH A SOPHISTICATED FLIGHT SIMULATOR. THERE WAS MUCH CONCERN FOR THE UNIQUE CIG SYSTEM TRANSPORT DELAY, AND TECHNIQUES WERE DEVELOPED WHICH PROVED TO BE QUITE SUCCESSFUL IN COMPENSATING FOR THE MAJORITY OF THIS DELAY. HOWEVER, NOT ENOUGH CONCERN WAS GIVEN TO PREVIOUSLY UNRECOGNIZED AND UNREPORTED EXCESSIVE MOTION SYSTEM DELAYS WHICH WERE ENCOUNTERED DURING FINAL INTEGRATED SYSTEM TESTS. THE INTEGRATION SCHEME AND THE IMPACT OF ITERATION RATES, VISUAL AND MOTION SYSTEM DELAYS, AND DELAY COMPENSATION ON VISUAL AND MOTION CUE COORDINATION AS PERCEIVED BY PILOTS ARE PRESENTED.

GUNDY, A.J.

THE ROLE OF MOTION IN FLIGHT SIMULATOR TRAINING: AN ALTERNATIVE INTERPRETATION OF SOME RECENT EVIDENCE. ROY AIR FORCE INSTITUTE OF AVIATION MEDICINE. IAM SCIENTIFIC MEMORANDUM NO. 123, MARCH 1975.

* ABSTRACT *

ROSCOE (1974) AND HOPKINS (1974) HAVE INTERPRETED THE RESULTS OF AN EXPERIMENT BY KENNEDY (1974) AS SHOWING THAT THE PRESENCE OR ABSENCE OF MOTION DURING SIMULATOR TRAINING MAKES NO DIFFERENCE TO THE TRANSFER OF TRAINING OBSERVED, THEREBY SUPPORTING THE CASE THAT MOTION SYSTEMS ARE NOT NECESSARY IN FLIGHT SIMULATORS USED FOR TRAINING. THIS REPORT SHOWS THAT THE DESIGN OF KENNEDY'S EXPERIMENT DOES NOT ALLOW THIS CONCLUSION TO BE DRAWN, SINCE THERE IS NO EVIDENCE THAT TRAINING OCCURRED.

GUNDY, A.J. THRESHOLDS TO ROLL MOTION IN A FLIGHT SIMULATOR. RAF INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH, HANTS, ENGLAND IN AIAA, VISUAL AND MOTION SIMULATION CONFERENCE, DAYTON, OHIO APRIL 26-28, 1976 (ALSO JOURNAL OF AIRCRAFT, VOLUME 14, NO. 7, PP. 624-631. JULY 1977.)

* ABSTRACT *

PROVIDING EFFECTIVE MOTION CUES REQUIRES THAT WE CAN FIRSTLY IDENTIFY THE ROLE OF MOTION IN FLIGHT SIMULATION, AND SECONDLY DESCRIBE THE AMOUNT AND TYPE OF MOTION NECESSARY TO FULFILL THAT ROLE. THE AUTHOR PRESENTS AN ANALYSES OF THESE PROBLEMS. ONE OF THE FIRST TASKS IS TO DEFINE THE SIMPLE THRESHOLD TO MOTION IN A FLIGHT SIMULATOR. DATA ON ROLL MOTION THRESHOLDS MEASURED IN A SMALL FLIGHT SIMULATOR IS PRESENTED. DURING THE NORMAL USE OF A SIMULATOR, THE PILOT DOES NOT HAVE THE SOLE TASK OF DETECTING MOTION. HE ALSO HAS TO FLY THE SIMULATOR. DATA IS ALSO PRESENTED UPON THE EFFECTS OF A CONCURRENT TASK UPON MOTION THRESHOLDS, WHICH WERE FOUND TO INCREASE AS THE COGNITIVE TASK BECAME MORE DEMANDING. IT IS CONCLUDED THAT THE CLASSICAL METHOD OF THRESHOLD MEASUREMENT MAY PRODUCE DATA THAT ARE MISLEADING IF USED AS THE BASIS OF MOTION SYSTEM DRIVE LAWS.

ARGUMENTS PRESENTED IN THIS PAPER AND THE ANOMALOUS RESULTS OF THE EXPERIMENT, MAKE IT CLEAR THAT THERE IS MUCH TO RECOMMEND THE ABANDONING OF THE SENSORY THRESHOLD TO MOTION AS A USEFUL CONCEPT FOR FLIGHT SIMULATION, AND TO USE INSTEAD VALUES OF AN 'EFFECTIVE THRESHOLD' TO MOTION, WHICH ARE DETERMINED BY OBSERVING AN OPERATOR'S CONTROL BEHAVIOR. HOWEVER, IT WAS PROPOSED THAT DATA CONCERNING 'EFFECTIVE THRESHOLDS' TO MOTION ARE NOT AS IMPORTANT AS DATA DESCRIBING 'ACCEPTABLE MOTION REQUIREMENTS', WHICH SHOULD BE DETERMINED USING THE TECHNIQUES OUTLINED IN THE FIRST PART OF THE PAPER.

GUNDY, A.C. MAN AND MOTION CUES. PAPER PRESENTED AT THE ROYAL AERONAUTICAL SOCIETY SYMPOSIUM ON 'THEORY AND PRACTICE IN FLIGHT SIMULATION', LONDON, ENGLAND, APRIL 1976.

* ABSTRACT *

THE AUTHOR ARGUES THAT THE ACCEPTABLE MOTION CUE REQUIREMENTS FOR FLIGHT SIMULATION SHOULD BE DETERMINED BY CONSIDERING THE EFFECT OF MOTION CUES ON THE OPERATOR'S CONTROL TASK.

SIMULATORS PROVIDE DISTURBANCE AND MANOEUVRE MOTIVATION, DEFINED AS CHANGES IN THE AIRCRAFT'S MOTION ARISING EXTERNALLY AND INTERNALLY, RESPECTIVELY, TO THE PILOT'S CONTROL LOOP. DISTURBANCE MOTION (E.G. TURBULENCE) MAY BE SIMULATED AT A FAIRLY FUNDAMENTARY LEVEL. MANOEUVRE MOTION (PRODUCED BY CONTROL ACTIVITY) NEEDS TO BE MORE ACCURATELY SIMULATED WHEN IT IS PROVIDED. HOWEVER, MANOEUVRE MOTION NEEDS ONLY TO BE PROVIDED WHEN AN UNSTABLE VEHICLE IS SIMULATED. IT IS SUGGESTED THAT THE VALUES OF MOTION CUE NECESSARY FOR THE SIMULATION OF PARTICULAR VEHICLES SHOULD BE DETERMINED BY DESCRIBING THE VALUES OF THAT MOTION CUE WHICH PRODUCE CONTROL ACTIVITY FROM THE PILOT WHICH IS ACCEPTABLY SIMILAR TO THAT PRODUCED IN FLIGHT.

THE AUTHOR NEXT DISCUSSES THE CHARACTERISTICS OF THE VESTIBULAR SYSTEM IN RELATION TO FLIGHT SIMULATION. ANGULAR MOTION CUES SHOULD BE DEFINED IN TERMS OF ANGULAR VELOCITY, SINCE OVER THE FREQUENCY BANDWIDTH OF CUES PROVIDED IN SIMULATORS, THE DYNAMIC RESPONSE AND THE THRESHOLD RESPONSE OF THE SEMICIRCULAR CANALS IS DETERMINED BY STIMULUS VELOCITY. THRESHOLDS ARE IMPORTANT IN FLIGHT SIMULATION TO FIX FLOOR AND CEILING VALUES FOR ONSET CUES AND WASHOUTS RESPECTIVELY, BUT THERE ARE INHERENT PHYSICAL AND PSYCHOLOGICAL DIFFERENCES BETWEEN LABORATORY STUDIES AND THE OPERATIONAL FLIGHT SIMULATOR. THESE DIFFERENCES ARE SO PROFOUND AS TO MAKE IT UNLIKELY THAT ABSOLUTE MOTION THRESHOLDS CAN BE EXTRAPOLATED FROM ONE TO THE OTHER. THE AUTHOR ARGUES FOR THE ADAPTATION OF EFFECTIVE THRESHOLDS TO MOTION IN SUBSTITUTION FOR SENSORY THRESHOLDS, THESE BEING DETERMINED FROM MINIMUM LEVELS OF MOTION WHICH ALTER COMPENSATORY TRACKING OUTPUT.

GUNDY, A.C. THRESHOLDS OF PERCEPTION FOR PERIODIC LINEAR MOTION. AVIAT. SPACE ENVIRON. MED. 49(5): 679-686, 1978.

* ABSTRACT *

THIS PAPER REVIEWS 18 REPORTS WHICH HAVE INVESTIGATED THE ABSOLUTE THRESHOLD OF PERCEPTION OF PERIODIC LINEAR MOTION. THE ROLES OF THE OTOLITH, SOMATOSENSORY, AND VISUAL DETECTION MECHANISMS IN DETERMINING THRESHOLD ARE DISCUSSED. MOST THRESHOLD DATA FOR OSCILLATION AT FREQUENCIES BELOW 1 HZ REFLECT OTOLITH AND SOMATOSENSORY DETECTION, AND SHOW A FALLING

THRESHOLD AS THE FREQUENCY RISES. THIS IS IN ACCORD WITH NEURO-
PHYSIOLOGICAL DATA OF OTOLITH AND SOMATOSENSORY FUNCTION. THE
DATA FOR FREQUENCIES ABOVE 1 HZ REFLECT AN UNKNOWN MIX OF VIS-
UAL, OTOLITH, AND SOMATOSENSORY INFLUENCES. THESE DATA ARE TOO
HETEROGENEOUS TO INDICATE WHETHER THRESHOLD RISES OR FALLS AS THE
FREQUENCY OF STIMULATION INCREASES.

GUNDY, A.C. EXPERIMENTS ON THE DETECTION OF ROLL MOTION.
AVIAT. SPACE ENVIRON. MED. 49(5): 657-664, 1978.

* ABSTRACT *

FOUR EXPERIMENTS INVESTIGATED THE DETECTION OF WHOLE-BODY ROLL
MOTION BY NORMAL ADULT MALES. EXPERIMENTS 1, 3, AND 4 EMPLOYED
AN EARTH-HORIZONTAL ROTATION AXIS, AND EXPERIMENT 2 AN EARTH-
VERTICAL ROTATION AXIS. COMPARISON OF EXPERIMENTS 1 AND 2
SHOWED THAT THE PRESENCE OF GRAVIRECEPTOR STIMULI INCREASED THE
RANGE OF DETECTABLE ANGULAR ACCELERATIONS AND REDUCED THE TIME
REQUIRED FOR DETECTION. IN EXPERIMENT 3, STIMULI WERE PRESENTED
FROM A SIDE-DOWN ORIENTATION AND THIS INCREASED DETECTION TIMES
WHEN COMPARED TO ROLL FROM THE UPRIGHT. EXPERIMENTS 1, 2, AND 3
USED BLINDFOLDED SUBJECTS; HOWEVER, EXPERIMENT 4 FOUND NO EFFECT
ON DETECTION TIMES OF VIEWING A HEAD-STABILIZED VISUAL TARGET.
THE OVERALL DATA SHOW DETECTION OF ANGULAR POSITION AND VELOCITY
AND SUGGEST SYNERGISTIC ACTION OF THE SEMICIRCULAR CANALS AND
GRAVIRECEPTORS. THE INFLUENCE OF SOMATOSENSORY STIMULI IS
CONSIDERED. FINALLY, IMPLICATIONS OF THE FINDINGS FOR FLIGHT
SIMULATORS ARE DISCUSSED.

WINNETT, W.E. - AMUSEMENT DEVICE
PATENT NO. 1,789,680
FILED OCT. 1, 1928 GRANTED JAN. 20, 1931

NO ABSTRACT

HAAS, R.L., HOLTZ, H.E. AND MILLS, G.R.
THE LARGE AMPLITUDE MULTI-MODE AEROSPACE RESEARCH (LAMAR) SIMU-
LATOR. AIAA PAPER NO. 73-922, AIAA VISUAL AND MOTION SIMULA-
TION CONFERENCE, PALO ALTO, CA, SEPTEMBER 10-12, 1973

* ABSTRACT *

THE LAMAR SIMULATOR, CURRENTLY BEING FABRICATED BY NORTHROP
CORPORATION FOR THE USAF FLIGHT DYNAMICS LABORATORY, IS
DISCUSSED IN THIS PAPER. THE USAGE OF THE SIMULATOR SYSTEM AND
HIGHLIGHTS OF ITS EVOLUTION ARE BRIEFLY OUTLINED; THE MAJOR
SUBSYSTEMS ARE DESCRIBED, WITH PRINCIPAL EMPHASIS ON THE

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FEATURES OF THE COCKPIT, MOTION SYSTEM AND VISUAL DISPLAY SYSTEM. MAJOR CONSIDERATIONS IN THE DETAIL FORMULATION OF THE CONCEPT ARE PRESENTED. THE PRINCIPAL NEW DESIGN FEATURES OF THIS SIMULATOR ARE:

- (A) THE MOTION SYSTEM'S TRAVEL LIMIT AND DECELERATION DEVICES AND
- (B) THE TARGET PROJECTOR WHICH HAS A DUAL CAPABILITY - TO PROJECT EITHER A NARROW-ANGLE (15 DEGREES) BEAM FOR A TARGET AIRCRAFT IMAGE OR A WIDE-ANGLE (60 DEGREES) BEAM FOR A DETAILED TERRAIN IMAGE. CRITERIA USED TO SPECIFY THE REQUIRED SYSTEM PERFORMANCE, AND REASONS FOR SELECTION OF THESE CRITERIA ARE ALSO INCLUDED.

HACKLER, C.T. MOTION EQUATIONS FOR HOVERING EXPERIMENT USING DYNAMIC PLATFORM. 'BELL HELICOPTER CORPORATION REPORT' C2PB-55C-005, APRIL 1960.

* ABSTRACT *

THE PURPOSE OF THIS REPORT WAS TO ACQUAINT PERSONNEL CONCERNED WITH CONDUCTING THE HOVERING EXPERIMENT USING THE DYNAMIC SIMULATOR PLATFORM WITH THE PROPOSED AIRFRAME EQUATIONS OF MOTION. THE EQUATIONS, REPRESENTING AN HTL-7, WERE COMPLETE, BUT COUPLING NETWORKS BETWEEN COMPUTER OUTPUT AND SIMULATOR INPUT WERE YET TO BE DETERMINED. THUS THE DISCUSSION WAS CONFINED TO THE MOTION EQUATIONS, THEIR MECHANIZATION, AND DYNAMIC RESPONSE TO IMPULSIVE CONTROL APPLICATIONS.

HALL, E.R., PARKER, J.F. JR., AND MEYER, D.E.
A STUDY OF AIR FORCE FLIGHT SIMULATOR PROGRAMS. USAF
AMFL-TR-67-111 AEROSPACE MEDICAL RESEARCH LABORATORIES, WRIGHT.
PATTERSON AFB, OHIO 1967

* ABSTRACT *

THIS REPORT DESCRIBES THE FLIGHT SIMULATOR UTILIZATION AND TRAINING PRACTICES WITHIN THE U.S. AIR FORCE. DATA ARE PRESENTED CONCERNING SIMULATOR TRAINING OBJECTIVES, CURRICULA, INSTRUCTIONAL METHODS, PERSONNEL, AND SUPPORT FACTORS WHICH AFFECT UTILIZATION AND PROGRAM EFFECTIVENESS. INFORMATION RELATING TO THE ACCEPTANCE OF FLIGHT SIMULATORS BY PILOT TRAINING PERSONNEL IS INCLUDED. IN ADDITION, RECOMMENDATIONS AND RESEARCH ISSUES ARE PRESENTED FOR IMPROVING THE EFFECTIVE UTILIZATION OF EXISTING FLIGHT SIMULATORS AND FOR THE DEVELOPMENT OF FUTURE SIMULATOR TRAINING REQUIREMENTS AND PROGRAMS.

HAMMERTON, M. 'TRANSFER OF TRAINING FROM A SIMULATED TO A REAL CONTROL SITUATION'. APPLIED PSYCHOLOGY RESEARCH UNIT, CAMBRIDGE, ENGLAND. 'JOURNAL OF EXPERIMENTAL PSYCHOLOGY', VOL. 66, NOV. 1963, P. 450-453.

* ABSTRACT *

THIS REPORTS AN EXAMINATION OF TRANSFER OF TRAINING WHEN TASKS DIFFERED ONLY IN DISPLAY APPEARANCE; ANGULAR CONTROL/DISPLAY RELATIONSHIPS WERE IDENTICAL. AN EXPERIMENTAL GROUP OF 11 UNSKILLED S'S WERE TRAINED ON A CRT TO CONTROL THE MOVEMENTS OF A TROLLEY MOVING ALONG A MINIATURE RAILWAY; A CONTROL GROUP OF 12 SS PRACTICED ON THE REAL TROLLEY AS INITIO. INITIAL TRANSFER WAS POOR (-17% BY ONE MEASURE); THE PERFORMANCE DECREMENT BEING PRONOUNCED (P LESS THAN .1%). SAVING, HOWEVER, WAS CONSIDERABLE (GREATER THAN 70%). CONCLUSIONS ARE

- (A) MOTOR RESPONSE IS NOT IMMEDIATELY TRANSFERRED, DESPITE IDENTICAL DYNAMICS AND DISPLAY KINEMATICS,
- (B) RECOVERY OF SKILL IS VERY RAPID
- (C) THESE FINDINGS MAY BE ATTRIBUTED TO STIMULUS COMPOUNDING.

HAMMERTON, M. MEASURES FOR THE EFFICIENCY OF SIMULATORS AS TRAINING DEVICES. 'ERGONOMICS', 10: 63-65, 1967.

* ABSTRACT *

THE DIFFICULTIES OF SELECTING SUITABLE MEASURES FOR THE EFFICIENCY OF SIMULATOR TRAINING DEVICES ARE DISCUSSED, AND SOME OF THE PITFALLS ARE POINTED OUT. SEVERAL FORMULAE ARE DISCUSSED IN LIGHT OF WHAT A POTENTIAL USER WOULD WISH TO KNOW, AND SOME ARE RECOMMENDED FOR USE.

HARDY, J.D. AND CLARK, C.C. 'THE DEVELOPMENT OF DYNAMIC FLIGHT SIMULATION', AERO/SPACE ENG. 1959, 18, 48-52.

* ABSTRACT *

TRACES BRIEFLY THE DEVELOPMENT OF DYNAMIC FLIGHT SIMULATORS FROM BEFORE WORLD WAR II. THE ARTICLE THEN TRACES THE DEVELOPMENT AND USE OF THE LARGE HUMAN CENTRIFUGE AT THE NAVAL AIR DEVELOPMENT CENTER, DESCRIBING ITS CAPABILITIES, ITS USE AND SOME OF THE RESULTS OBTAINED IN THE X-15 SIMULATION PROGRAM. FINALLY, IT EVALUATES BRIEFLY THE CENTRIFUGE AS A DYNAMIC FLIGHT SIMULATOR.

NAVTRAEGUIPCEN IH-298

HARPER, C.W. SIMULATION FOR AEROSPACE RESEARCH. NORTH ATLANTIC TREATY ORGANIZATION, 'ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT', AGARDBGRAPH 99, FEB. 1964.

* ABSTRACT *

THIS AGARDBGRAPH CONTAINS EIGHT PAPERS PRESENTED AT THE 24TH AGARD FLIGHT MECHANICS PANEL MEETING, AMES RESEARCH CENTER, CALIFORNIA, USA, IN FEBRUARY, 1964. THREE MAJOR ASPECTS OF SIMULATION ARE DEALT WITH. FIRST, THE ELECTRO-MECHANICAL-OPTICAL SYSTEMS FORMING THE SIMULATION HARDWARE AND THE ASSOCIATED COMPUTING FACILITIES; SECOND, EXAMPLES OF SIMULATION RESEARCH APPLIED TO AIRCRAFT PROBLEMS; AND THIRD, EXAMPLES OF SIMULATION RESEARCH APPLIED TO SPACECRAFT PROBLEMS. A DISCUSSION OF THE SIMULATION RESEARCH PROBLEM FROM A HUMAN ENGINEERING STANDPOINT PRECEDES THE HARDWARE, AIRCRAFT AND SPACECRAFT SECTION. (AUTHOR)

HARRIS, W. T.
ACCEPTANCE TESTING OF FLYING QUALITIES AND PERFORMANCE,
COCKPIT MOTION, AND VISUAL DISPLAY SYSTEM SIMULATION FOR FLIGHT
SIMULATORS.
'NAVAL TRAINING EQUIPMENT CENTER'
REPORT NAVTRAEGUIPCEN IH-251, MAY 1977.

* ABSTRACT *

TODAY'S FLIGHT SIMULATORS ARE BEING CALLED UPON TO PROVIDE TRAINING IN OBTAINING BASIC FLIGHT SKILLS AS WELL AS THE MAINTENANCE OF FLIGHT SKILLS AND SYSTEM OPERATION PROFICIENCY BY EXPERIENCED AVIATORS. IN SOME CASES, THE ACCEPTABILITY OF THE FLIGHT SIMULATORS PURCHASED BY THE U.S. NAVY HAS BEEN LESS THAN DESIRED. THIS STUDY ADDRESSED THREE AREAS OF ACCEPTANCE TESTING; IN PARTICULAR, FLYING QUALITIES AND PERFORMANCE, COCKPIT MOTION AND VISUAL SIMULATION. PROPOSED SPECIFICATION LANGUAGES DETAILING TESTS TO BE PERFORMED, RECOMMENDED PROCEDURES, TEST CRITERIA AND SUGGESTED TOLERANCES ARE INCLUDED AS APPENDIXES. THESE APPENDIXES MAY BE DETACHED FOR INDEPENDENT USE.

HAYDEN, W.D. ANALYTIC TECHNIQUE FOR ESTABLISHING THE MOTION REQUIREMENTS FOR A GROUND-BASED AIRCRAFT SIMULATOR. 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE PAPER' 70-348, CAPE CANAVERAL, FL, MAR 16-18, 1970.

* ABSTRACT *

AN ANALYTIC TECHNIQUE WAS USED TO ESTABLISH THE MOTION REQUIREMENTS FOR A MOVING-BASE FLIGHT SIMULATOR. SEVERAL MOTION DRIVE TECHNIQUES FOR THE MOVING BASE ARE EVALUATED FROM

WHICH A WASHOUT TYPE DRIVE CONCEPT IS SELECTED. THE SELECTED DRIVE TECHNIQUE AND THE EQUATIONS OF MOTION FOR AN AIRCRAFT ARE PROGRAMMED IN A COMPUTER. TIME HISTORIES OF AIRCRAFT CONTROL SURFACE DEFLECTIONS DURING TYPICAL AIRCRAFT MANEUVERS ARE USED AS INPUTS TO THE AIRCRAFT EQUATIONS OF MOTION. THE RESULTING AIRCRAFT ACCELERATIONS ARE USED AS DRIVING INPUTS TO A SIMULATED MOVING BASE FLIGHT SIMULATOR MECHANIZED IN THE COMPUTER. BASED ON THE TIME HISTORIES OF THE SIMULATED BASE MOTIONS, THE MAXIMUM VALUES OF ACCELERATION, VELOCITY, AND DISPLACEMENT REQUIRED FOR EACH AXIS OF THE SIMULATOR ARE DETERMINED. A COMPARISON OF THE SIMULATOR TO THE AIRCRAFT ACCELERATIONS AT THE PILOT'S STATION PROVIDES PERTINENT INFORMATION RELATIVE TO THE DEGREE OF PERCEPTUAL FIDELITY OBTAINED FOR EACH SIMULATED MANEUVER. (AUTHOR)

HEINLE, D.R. 'THE USE OF PILOTED SIMULATORS IN THE STUDY OF VTOL FLIGHT'. NASA CONFERENCE ON VTOL AIRCRAFT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, LANGLEY. 1960.

* ABSTRACT *

INVESTIGATION OF TRANSITION CHARACTERISTICS WITHIN BOUNDARIES IMPOSED BY AIRSPEED, ANGLE OF ATTACK AND STRUCTURAL LIMITS OF FLAP DEFLECTION. STATIC SIMULATION MADE IT VERY DIFFICULT OR IMPOSSIBLE FOR PILOTS TO EFFECT TRANSITION AT ALL. PITCH AND ROLL COCKPIT MOTIONS ALLOWED PILOTS TO EXPLORE AND COMMENT ON A WIDE REGION OF TRANSITION CONDITIONS.

INVESTIGATION OF HOVER CHARACTERISTICS IN STATIC SIMULATION AND WHEN ROLL COCKPIT MOTIONS ADDED. ROLL CUES PERMITTED BETTER CONTROL OF SWAY VELOCITY AND ROLL VELOCITY.

HELD, R., DICHGANS, J. AND BAUER, J. CHARACTERISTICS OF MOVING VISUAL SCENES INFLUENCING SPATIAL ORIENTATION. 'VISION RESEARCH', VOL. 15, PP. 357-365, PERGAMON PRESS, MAR. 1975.

* ABSTRACT *

A VISUAL DISPLAY ROTATING IN A FRONTAL PLANE INDUCES EFFECTS EQUIVALENT TO A CHANGE IN THE APPARENT DIRECTION OF GRAVITY. MAGNITUDE OF VISUAL TILT WAS MEASURED AS A FUNCTION OF TIME FROM ONSET OF ROTATION, VELOCITY OF ROTATION AND AREA AND RETINAL LOCATION OF THE STIMULATING FIELD. THE MAJOR PART OF THE TILT OCCURS WITHIN 30 SEC FROM ONSET OF STIMULATION. IT INCREASES WITH ANGULAR VELOCITY, BUT INDEPENDENTLY OF AREA AND LOCATION OF FIELD, UP TO ABOUT 30 TO 40 OF ROTATION PER SEC AND THEN LEVELS OFF. TILT INCREASES WITH FIELD SIZE BUT THE EFFECT OF THIN RING FIELDS INCREASES WITH RETINAL ECCENTRICITY. THE INTERACTION OF VISUAL AND NONVISUAL DETERMINANTS OF THE INDUCED EFFECTS IS DISCUSSED.

W. FELMORE - MECHANISMS FOR SIMULATING THE MOVEMENT OF VEHICLES
PATENT NO. 3,309,795
DATE FILED - JULY 12, 1961 DATE GRANTED - MARCH 21, 1967

NO ABSTRACT

HERRMANN, C. - AMUSEMENT DEVICE
PATENT NO. 2,528,516
FILED MARCH 23, 1945 GRANTED NOV. 7, 1950

NO ABSTRACT

HESS, R.A. A METHOD FOR GENERATING NUMERICAL PILOT OPINION RATINGS USING THE OPTIMAL PILOT MODEL. JAMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, NASA TECHNICAL MEMORANDUM NASA TMX73,101, WASH.INGTON, D.C., 1976.

* ABSTRACT *

A METHOD FOR GENERATING NUMERICAL PILOT OPINION RATINGS USING THE OPTIMAL PILOT MODEL IS INTRODUCED. THE METHOD IS CONTAINED IN A RATING HYPOTHESIS WHICH STATES THAT THE NUMERICAL RATING WHICH A HUMAN PILOT ASSIGNS TO A SPECIFIC VEHICLE AND TASKS CAN BE DIRECTLY RELATED TO THE NUMERICAL VALUE OF THE INDEX OF PERFORMANCE RESULTING FROM THE OPTIMAL PILOT MODELING PROCEDURE AS APPLIED TO THAT VEHICLE AND TASK. THE HYPOTHESIS IS TESTED USING THE DATA FROM FOUR PILOTED SIMULATIONS. THE RESULTS INDICATE THAT THE HYPOTHESIS IS REASONABLE, BUT THAT THE PREDICTIVE CAPABILITY OF THE METHOD IS A STRONG FUNCTION OF THE ACCURACY OF THE PILOT MODEL ITSELF. THIS ACCURACY IS, IN TURN, DEPENDENT UPON THE PARAMETERS WHICH DEFINE THE OPTIMAL MODELING PROBLEM. A PROCEDURE FOR SPECIFYING THE PARAMETERS FOR THE OPTIMAL PILOT MODEL IN THE ABSENCE OF EXPERIMENTAL DATA IS SUGGESTED.

HILL ET AL - KINESTHETIC CONTROL SIMULATOR
PATENT NO. 3,859,736
FILED APRIL 20, 1970 GRANTED JAN. 14, 1975

NO ABSTRACT

HILL, P.R., THOMAS, DAVID F. JR.
KINESTHETIC CONTROL SIMULATOR. 'U.S. PATENT', NASA, FILED
APRIL 20, 1970.

* ABSTRACT *

A KINESTHETIC CONTROL SIMULATOR HAVING A FLAT BASE UPON WHICH RESTS A SUPPORT STRUCTURE HAVING A LOWER SPHERICAL SURFACE FOR ROTATION ON THE BASE PLATE WITH COLUMNS WHICH SUPPORT A PLATFORM ABOVE THE SUPPORT STRUCTURE AT A DESIRED LOCATION WITH RESPECT TO THE CENTER OF CURVATURE OF THE SPHERICAL SURFACE. A HANDRAIL IS AT APPROXIMATELY THE ELEVATION OF THE HIPS OF THE OPERATOR ABOVE THE PLATFORM WITH A RING ATTACHED TO THE SUPPORT STRUCTURE WHICH MAY BE USED TO LIMIT THE ANGLE OF TILT. FIVE DEGREES OF FREEDOM-OF-MOTION CAN BE OBTAINED BY UTILIZING AN AIR PAD STRUCTURE FOR SUPPORT OF THE CONTROL SIMULATOR.

FIRSCH, M.C. AND WEYMOUTH, F.W.
DISTANCE DISCRIMINATION: V. EFFECT OF MOTION AND DISTANCE OF TARGETS ON MONOCULAR AND BINOCULAR DISTANCE DISCRIMINATION.
'AVIATION MEDICINE', DECEMBER 1947.

* ABSTRACT *

THE TESTS AT PRESENT USED FOR THE MEASUREMENT OF DEPTH ACUITY ARE DESIGNED TO ELIMINATE THOSE INDIVIDUALS WHO POSSESS OR HABITUALLY USE ONLY ONE EYE. UNDER THE CONDITIONS OF THE TEST, BINOCULAR DEPTH ACUITY IS UNQUESTIONABLY MANY TIMES AS SENSITIVE AS MONOCULAR. HOWARD FOUND MONOCULAR THRESHOLDS TWENTY TIMES AS GREAT AS BINOCULAR THRESHOLDS FOR NINE OBSERVERS, WHILE DEYB, TESTING ONE HUNDRED AVIATORS AT MITCHELL FIELD WITH THE REGULATION HOWARD-DOLMAN APPARATUS, FOUND THRESHOLDS WHICH AVERAGED 6.35 TIMES AS GREAT FOR MONOCULAR AS FOR BINOCULAR. THE DISCREPANCY BETWEEN THE TWO MAY BE ACCOUNTED FOR AT LEAST PARTLY BY THE FACT THAT HOWARD USED A CONSTANT METHOD OF STIMULUS PRESENTATION THE 75 PERCENT POINT AS THE THRESHOLD, WHILE DEYB EMPLOYED THE AVERAGE ERROR METHOD CUSTOMARILY USED WITH THE HOWARD-DOLMAN APPARATUS. CLEARLY, HOWEVER, AT THE 6 METER DISTANCE AND USING THE HOWARD APPARATUS, BINOCULAR THRESHOLDS ARE MANY TIMES LOWER THAN MONOCULAR. THE HOWARD TEST, HOWEVER, IS UTILIZED TO SELECT AVIATORS WHOSE JUDGMENTS OF SPATIAL LOCALIZATION WILL BE MADE NOT OF THE USUAL STATIONARY TARGETS, BUT OF A FIELD IN MOTION. FURTHERMORE, THE TEST IS CUSTOMARILY ADMINISTERED AT 6 METERS WHILE THE TASKS ARE CARRIED OUT AT VERY MUCH GREATER DISTANCES. THUS, TWO DISCREPANCIES EXIST BETWEEN THE TASK AND THE TEST, THAT OF DISTANCE AND THAT OF MOTION. IT IS THE PURPOSE OF THIS PAPER TO EXAMINE THE EFFECT OF THESE TWO VARIABLES UPON BOTH MONOCULAR AND BINOCULAR THRESHOLDS OF DISTANCE DISCRIMINATION.

THE RESULTS INDICATE THAT WE MUST SERIOUSLY QUESTION THE VALIDITY OF THE HOWARD-DOLMAN TEST AS A USEFUL DEVICE IN

SELECTING AVIATORS. WHILE THIS DEVICE SUCCESSFULLY ELIMINATED FUNCTIONALLY MONOCULAR INDIVIDUALS, THE MONOCULAR INDIVIDUAL MAY BE AS WELL OF AS THE BINOCULAR ONE WHEN THE GREATER DISTANCES OF AVIATION ARE ENCOUNTERED AND WHEN THE TARGETS ARE NOT STATIONARY BUT IN MOTION. THE FACTORS OF DISTANCE AND MOTION HERE DISCUSSED MAY WELL EXPLAIN THE SUCCESS OF MONOCULAR PILOTS, NOTABLY WILEY POST, IN THE PAST. IT IS UNFORTUNATE THAT THE FACTORS OF MOTION AND DISTANCE COULD NOT BE INCORPORATED INTO A SINGLE TEST, IF A SUITABLE APPARATUS COULD BE DEvised, THE TESTING OF BOTH MONOCULAR AND BINOCULAR VISION WITH AND WITHOUT MOTION AT DISTANCES MORE NEARLY COMPARABLE WITH THOSE ENCOUNTERED IN AVIATION MIGHT GIVE GREATER PREDICTIVE VALUE TO PRELIMINARY TESTS.

HITCHCOCK, L., JR. AND MORWAY, D.A.
 A DYNAMIC SIMULATION STUDY OF THE SWEEP-WING TRANSPORT AIRCRAFT
 IN SEVERE TURBULENCE. U.S. NAVAL AIR DEVELOPMENT CENTER.
 NAARC-MR-6807, JOHNSVILLE, PA. OCTOBER 1968.

* ABSTRACT *

THE HUMAN CENTRIFUGE, HOUSED AT THE AEROSPACE MEDICAL RESEARCH DEPARTMENT OF THE NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, WARMINSTER, PENNSYLVANIA HAS SERVED AS A MOTION SIMULATOR FOR ALL OF THE NATION'S MANNED SPACECRAFT. IN 1964, THE FEDERAL AVIATION AGENCY ELECTED TO USE THIS FACILITY AND EXPERIENCE TO STUDY THE PROBLEM OF SEVERE TURBULENCE PENETRATION BY SWEEP-WING JET TRANSPORT AIRCRAFT. THIS REPORT DISCUSSES THE METHODS EMPLOYED IN PRODUCING THE GROUND-BASED, CLOSED-LOOP DYNAMIC SIMULATION AND THE RESULTS THAT WERE OBTAINED. THE BOEING 720-B WAS SELECTED AS THE BASIC AIRCRAFT FOR THIS SIMULATION BECAUSE OF ITS EXTENSIVE USE IN COMMERCIAL OPERATIONS AND THE AVAILABILITY OF THE NECESSARY AERODYNAMIC DATA. A MOCK-UP OF THE 720 COCKPIT INCLUDING FUNCTIONAL FLIGHT INSTRUMENTS AND CONTROLS WAS FABRICATED AND INSTALLED UPON A HYDRAULICALLY-ACTIVATED SHAKE TABLE MOUNTED INSIDE THE CENTRIFUGE GONDOLA. THE CENTRIFUGE WAS USED TO SIMULATE THE LONG-TERM ACCELERATIONS ASSOCIATED WITH FLIGHT PATH CHANGES. THE SHAKE TABLE REPRODUCED THE HIGHER FREQUENCY LOAD CHANGES ASSOCIATED WITH SHORT-TERM AERODYNAMIC RESPONSE, FIRST BENDING MOMENT (FUSELAGE, RESONANCE) AND STALL AND MACK BUFFETS. A COMPUTER ANALOG OF THE 720-B AERODYNAMICS AND EQUATION OF MOTION WAS PROGRAMMED INTO THE CENTRIFUGE CONTROL COMPUTER. THE SIMULATION WAS FULLY CLOSED LOOP, IN THAT THE SUBJECT PILOTS ACTUALLY 'FLEW' THE CENTRIFUGE THROUGH THE 720 COMPUTER PROGRAM. THE COMPUTER PRESENTED REALISTIC FLIGHT INSTRUMENT DISPLAYS AND ALSO COMMANDED THE CENTRIFUGE MOTIONS TO REPRODUCE THE ACCELERATIONS WHICH WOULD BE EXPERIENCED BY THE PILOT UNDER SIMILAR CONDITIONS IN THE ACTUAL AIRCRAFT. MAGNETIC TAPE RECORDINGS OF TURBULENCE WERE OBTAINED FROM THE NATIONAL SEVERE STORMS PROJECT. THESE TAPES MADE POSSIBLE THE INTRODUCTION OF SEVERE TURBULENCE IN THE AIRCRAFT COMPUTER ANALOG AT ANY

SELECTED POINT IN THE SIMULATED FLIGHT. THE MAGNETIC TAPE STORM CONSISTED OF BOTH LATERAL AND VERTICAL GUST RECORDINGS WHICH WERE INTRODUCED DIRECTLY INTO THE AIRCRAFT AERODYNAMICS AS CHANGES IN ANGLE OF ATTACK AND SIDE-SLIP ANGLE, TO PRODUCE REALISTIC ATMOSPHERIC DISTURBANCES OF THE AIRCRAFT. MOST OF THE MAJOR COMMERCIAL AIRLINES INCLUDING REPRESENTATIVES FROM FIVE FOREIGN COUNTRIES VOLUNTARILY PARTICIPATED IN THIS STUDY. MORE THAN 100 AIRLINE CAPTAINS MADE TURBULENCE PENETRATION FLIGHTS IN THE 720-B CENTRIFUGE SIMULATOR. THE DATA OBTAINED WERE ANALYZED PRIMARILY IN TERMS OF THE PROBABILITY DISTRIBUTION OF PEAK VALUES OF THE PRIMARY FLIGHT PARAMETERS ACROSS INDIVIDUAL PILOT RUNS. IN ADDITION, THE CONCEPT OF PROBABLE VELOCITY LOAD (PVN) DIAGRAMS WAS DEVELOPED TO BETTER DESCRIBE AND COMPARE FLIGHT CONDITIONS. THE CONCLUSIONS THAT WERE DERIVED FROM THE CENTRIFUGE TURBULENCE PENETRATION SIMULATION MAY BE SUMMARIZED AS FOLLOWS. THE QUALITY OF THE TURBULENCE SIMULATION WAS SUBJECTIVELY EVALUATED BY ALL OF THE SUBJECT AIRLINES PILOTS AS BEING EXTREMELY REALISTIC. TEST DATA CLEARLY DEMONSTRATED THAT THE CURRENT RECOMMENDED PENETRATION PROCEDURES ARE FOR THE MOST PART ADEQUATE AND THAT THE PILOTS WERE QUITE WILLING TO AND CAPABLE OF COMPLYING WITH THESE PROCEDURES. AN ELEMENTARY 'TURBULENCE FLIGHT DIRECTOR' PROVED TO BE A VERY SUCCESSFUL MEANS OF PROVIDING THE PILOTS WITH INFORMATION ENABLING THEM TO MAINTAIN MORE PRECISE SPEED CONTROL AND REDUCED LOAD FACTOR.

PREY, R.G. CORRELATION OF X-15 SIMULATION EXPERIENCE WITH FLIGHT TEST RESULTS. NORTH ATLANTIC TREATY ORGANIZATION, ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT, AGARD REPORT 530, 1966.

* ABSTRACT *

THE USAF AND NASA HAVE RELIED HEAVILY UPON ENGINEERING SIMULATORS DURING THE PREPARATION FOR AND CONDUCT OF THE X-15 ROCKET POWERED RESEARCH AIRPLANE FLIGHT TEST PROGRAM. THIS PAPER DESCRIBES THE SIMULATIONS USED IN THE PROGRAM AND COMPARES SIMULATION RESULTS WITH ACTUAL FLIGHT TEST RESULTS. FLIGHT AND SIMULATOR PILOT RATINGS ARE COMPARED OVER A RANGE OF HANDLING QUALITIES FROM EXCELLENT TO UNCONTROLLABLE. FLIGHT TRAJECTORIES ARE PRESENTED AND COMPARED WITH SIMULATOR PREDICTIONS. APPARENT VARIATIONS BETWEEN SIMULATOR PREDICTIONS AND ACTUAL FLIGHT RESULTS ARE DISCUSSED AS TO THEIR CAUSE AND THEIR EFFECT ON SIMULATION CONFIDENCE. IMPROVEMENTS TO THE SIMULATORS RESULTING FROM FLIGHT TEST DATA AND PILOT COMMENTS ARE ALSO DISCUSSED.

INCLUDED IS A DESCRIPTION OF A REAL-TIME SIMULATION OF AERODYNAMIC HEATING AND ABLATION, THE MANNER IN WHICH THIS SIMULATION WILL BE USED DURING THE X-15 FLIGHT ENVELOPE EXPANSION FROM MACH 6 TO 8, AND COMPARISON OF HEATING SIMULATION RESULTS WITH DATA OBTAINED TO DATE.

HOLLEMAN, E.C. AND WILSON, W.S. FLIGHT-SIMULATOR REQUIREMENTS FOR HIGH-PERFORMANCE AIRCRAFT BASED ON X-15 EXPERIENCE. THE 'AMERICAN SOCIETY OF MECHANICAL ENGINEERS' ASME PAPER 63-AHGT-81 JAN. 1963

* ABSTRACT *

SIMULATION EXPERIENCE OBTAINED DURING THE DESIGN AND FLIGHT TESTING OF THE X-15 RESEARCH AIRPLANE IS REVIEWED. THE PROBLEMS ENCOUNTERED AND THE USE OF SIMULATORS TO SOLVE THESE PROBLEMS ARE DISCUSSED. SIMULATION TECHNIQUES WHICH MAY BE USED IN THE SUPER-SONIC-TRANSPORT PROGRAM ARE CONSIDERED.

DURING THESE RESEARCH MISSIONS, A PILOT EVALUATION OF THE SIMULATED MISSION AND THE ACTUAL FLIGHT WAS OBTAINED. IN GENERAL, THE PILOT RATINGS OF THE FIXED-BASE SIMULATOR AND ACTUAL FLIGHT SHOWED GOOD AGREEMENT. THESE DATA INCLUDED ALTITUDE MISSIONS INVOLVING EXIT ACCELERATIONS OF 3G, NEAR OG, AND REENTRY ACCELERATIONS OF APPROXIMATELY 5G.

THE PILOTS INDICATED THAT THE CENTRIFUGE SIMULATIONS WERE WORTHWHILE AND NECESSARY IN GAINING A FEELING FOR HIGH ACCELERATIONS. HOWEVER, THEY FELT THAT AFTER EXPERIENCING THE ACCELERATION EFFECTS IN THE CENTRIFUGE, THE FIXED-BASE SIMULATOR WAS ADEQUATE PREPARATION FOR THE EXTREME X-15 MISSIONS.

HARKINS, B. PROPRIOCEPTION AND/OR KINESTHESIS PERCEPTUAL AND MOTOR SKILLS, 1972, 34, 431-435.

* ABSTRACT *

A SHORT REVIEW OF THE LITERATURE POINTS TO THE CONFUSED USAGE OF 'PROPRIOCEPTION' AND 'KINESTHESIS' WHICH IS INCOMPATIBLE WITH THE OBJECTIVENESS DEMANDED OF CONTEMPORARY PSYCHOLOGY. THE HISTORICAL DEVELOPMENT OF THE TERMS IS TRACED SHOWING THAT 'KINESTHESIS' HAS UNDERGONE A CHANGE IN MEANING, RENDERING ITS PRESENT STATE OF DEFINITION INADEQUATE FOR THE STRINGENCIES OF EXPERIMENTAL WORK. RECOMMENDATIONS ARE MADE FOR A MORE OBJECTIVE DESCRIPTION OF FEEDBACK MECHANISMS.

HARKINS, C.B. HOW MUCH SHOULD YOU PAY FOR THAT BOX. (PRESIDENTIAL ADDRESS, HUMAN FACTORS SOCIETY, AVIATION RESEARCH LABORATORY, INSTITUTE OF AVIATION, UNIVERSITY OF ILLINOIS, URBANA. CHAMPAIGN, TECHNICAL REPORT ARL-74-11/AFOSR-74-6, OCTOBER, 1974.

* ABSTRACT *

CAPTAIN RHODES NOTED THAT ALL HIS AIRCRAFT FLY LIKE AIRCRAFT. 707'S FOR EXAMPLE, FLY LIKE 707'S. HIS SIMULATORS DO NOT FLY LIKE AIRCRAFT AND MY SIMPLISTIC ANSWER IS THAT THE REASON THEY DO NOT FLY LIKE AIRCRAFT IS THAT THEY ARE NOT AIRCRAFT. THE SIMULATOR IS FUNDAMENTALLY A BOX SITTING ON THE GROUND. (TAIT, 1972)

THESE REMARKS ARE QUOTED FROM A COMMENTARY AT A SIMULATION SUBCOMMITTEE WORKSHOP SPONSORED BY THE AIR TRANSPORT ASSOCIATION. MANY MILLIONS OF DOLLARS HAVE BEEN SPENT AND ARE BEING SPENT NOW FOR AIRCRAFT SIMULATORS. AN AIRLINE'S L-1011 AIRCRAFT SIMULATOR COST 2.3 MILLION AND THE F-4J AIRCRAFT SIMULATOR FOR THE NAVY COST 5 MILLION. MANY MORE MILLIONS OF DOLLARS HAVE BEEN PROGRAMMED TO BE SPENT. DEVELOPMENT CONTRACTS TOTALING 31 MILLION WERE AWARDED BY THE AIR FORCE IN 1971 AND 1972 TO BUILD TWO EXPERIMENTAL SIMULATORS AND THAT WAS JUST A BEGINNING.

WHY IS SO MUCH MONEY BEING SPENT FOR SIMULATORS. QUITE OBVIOUSLY BECAUSE THERE IS A WIDESPREAD BELIEF THAT SIMULATORS ARE USEFUL AND THAT THEIR USEFULNESS JUSTIFIES THEIR COST. YET, THE VICE PRESIDENT AND DIRECTOR OF ENGINEERING OF A COMPANY THAT MANUFACTURES AND SELLS SIMULATORS REFERRED TO THE SIMULATOR AS FUNDAMENTALLY A BOX SITTING ON THE GROUND. HOW DOES IT HAPPEN THAT THE BOX CAN COST SO MUCH AND THAT SOME CUSTOMERS ARE WILLING TO PAY THE EXORBITANT COST. BEFORE GRAPPLING WITH THE ANSWERS TO THESE QUESTIONS, SOME BACKGROUND IS NECESSARY.

IN THE SECTION OF THE PAPER CONCERNING SIMULATION MOTION AND TRANSFER OF TRAINING, DR. HOPKINS DISCUSSES MAJOR KOONCE'S (1974) EXPERIMENT AND CONCLUDES THAT, CERTAINLY, THERE IS NO EVIDENCE THAT SIMULATOR MOTION OF EITHER OF THE TWO TYPES USED ENHANCED TRANSFER OF TRAINING FROM THE SIMULATOR TO THE AIRCRAFT. ON THE CONTRARY, IT MAY VERY WELL BE THE CASE THAT WITH SIMULATOR MOTION, PILOTS LEARN TO RESPOND TO ACCELERATION CUES THAT MAY NOT BE PRESENT IN FLIGHT BECAUSE MUCH AIRCRAFT MOTION INVOLVES ACCELERATIONS THAT ARE BELOW DETECTION THRESHOLD.

HOPKINS, C.B. SIMULATORS FOR TRAINING AND PROFIT --- COST EFFECTIVENESS. UNIV. OF ILLINOIS (SAVOY AVIATION RESEARCH LAB.), URBANA-CHAMPAIGN, REPORT ARL-76-10/AFOSR-76-5, AFOSR-77-0373TR, JULY 1976.

* ABSTRACT *

THE USE OF SIMULATORS FOR TRAINING AND PROFIT IS DISCUSSED IN TERMS OF THE CONCEPT OF COST EFFECTIVENESS. INCREASED DEGREE AND FIDELITY OF SIMULATION REQUIRE GREATER EQUIPMENT COMPLEXITY AND COST. DATA ARE PRESENTED THAT SHOW A HIGH NEGATIVE CORRELATION BETWEEN COST AND FIELD RELIABILITY OF AVIONICS EQUIPMENT.

THERE IS A FALCITY OF RESEARCH DATA ON THE RELATIONSHIPS BETWEEN SIMULATOR FIDELITY AND TRANSFER EFFECTIVENESS. THE RESULTS OF THE FIRST AND ONLY RECENTLY COMPLETED EXPERIMENT TO INVESTIGATE TRANSFER OF INITIAL FLIGHT TRAINING AS A FUNCTION OF SIMULATOR COCKPIT MOTION ARE SUMMARIZED. A RATIONAL BASIS FOR SIMULATOR SELECTION AND USE DEVELOPED BY JACOBS AND ROSCOE IS PRESENTED. THE NEED FOR RESEARCH TO ESTABLISH RELATIONSHIPS BETWEEN TRANSFER OF TRAINING AND PHYSICAL CHARACTERISTICS SUCH AS DEGREE AND FIDELITY OF SIMULATION IS SEEN AS CRITICAL TO THE WIDESPREAD FUTURE USE OF SIMULATORS FOR TRAINING AND PROFIT.

HERBOWITZ, M.W. AND WELLS, C.F. 'ANALYSIS OF COCKPIT MOTIONS NEEDED FOR OPERATIONAL FLIGHT TRAINERS', REPORT NO. 20-05-51, EDUCATIONAL RESEARCH CORP. AND U.S. NAVAL TRAINING DEVICES CENTER, PORT WASHINGTON, NEW YORK, 1958.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO EVALUATE COCKPIT MOTION AS A MEANS OF ENHANCING TRAINING IN OPERATIONAL FLIGHT TRAINERS (OFT). THE ANALYSIS WAS BASED ON:

- (1) A LITERATURE SEARCH OF THRESHOLD DISCRIMINATIONS FOR VARIOUS KINDS OF MOTION
- (2) ON-GOING RESEARCH UTILIZING MOTION PLATFORMS
- (3) OPINIONS OF PERSONNEL WORKING WITH MOTION PLATFORMS, AND
- (4) THE AUTHOR'S SUBJECTIVE EVALUATION OF OFT'S INCORPORATING MOTION PLATFORMS.

ON THE BASIS OF THE ABOVE SURVEY, THE AUTHORS RECOMMEND THAT COCKPIT MOTION CAPABILITIES BE INCLUDED IN FLIGHT TRAINERS.

BARSEFIELD, W.D. T.S.R.2. - A COMPARISON OF ACTUAL HANDLING QUALITIES WITH ESTIMATES. NORTH ATLANTIC TREATY ORGANIZATION, ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT, AGARD REPORT 534, MAY 1966.

* ABSTRACT *

THE T.S.R.2 WAS FLOWN OVER A SIGNIFICANT PART OF ITS FLIGHT ENVELOPE BEFORE ITS CANCELLATION. PILOT OPINION ON ITS HANDLING QUALITIES IS COMPARED WITH SIMULATION EXPERIENCE AND PREDICTION BASED ON VARIOUS CRITERIA. FLIGHT OPINION WAS IN GENERAL MORE FAVOURABLE THAN EXPECTED. THE REASONS FOR THIS ARE EXPLAINED AND DISCUSSED, BEING IN PART DUE TO DIFFERENCES IN DERIVATIVES BETWEEN FLIGHT AND ESTIMATES BASED ON WIND TUNNEL DATA.

THIS PAPER WAS PRESENTED AT THE TWENTY-EIGHTH MEETING OF THE AGARD FLIGHT MECHANICS PANEL, HELD IN PARIS, FRANCE, ON 10-11 MAY, 1966.

HOSMAN, R.V.A.W. AND VAN DER VAART, J.C. THRESHOLDS OF MOTION PERCEPTION MEASURED IN A FLIGHT SIMULATOR. JAN. 1976.

* ABSTRACT *

HUMAN ROTATIONAL AND TRANSLATIONAL THRESHOLDS WERE MEASURED USING A HYDRAULIC MOTION BASE WITH HYDROSTATIC BEARINGS. RESULTS SHOWED THAT THE ANGULAR MOTION THRESHOLDS WERE FREQUENCY DEPENDENT AND ALL VALUES WERE A FUNCTION OF PILOT TASK LOADING.

HOWARD, I.F. AND TEMPLETON, W.B. 'HUMAN SPATIAL ORIENTATION'. JOHN WILEY & SONS: NEW YORK 1966.

* ABSTRACT *

THIS BOOK IS ABOUT THOSE ASPECTS OF HUMAN BEHAVIOUR WHICH ARE DETERMINED BY THE ANGULAR POSITION OF THE BODY (OR HEAD) IN RELATION TO ANY STABLE EXTERNAL REFERENCE SYSTEM. STRICTLY SPEAKING, THIS DEFINITION OF THE BOOK'S SCOPE EXCLUDES JUDGMENTS OF THE INCLINATION OF LINES TO GRAVITY, FOR THERE ONLY EXTERNAL REFERENCE AXES ARE DIRECTLY INVOLVED. HOWEVER, THIS TOPIC IS IMPORTANT FOR AN UNDERSTANDING OF BODY ORIENTATION BEHAVIOUR AND IS INCLUDED FOR THAT REASON. OTHER TOPICS, SUCH AS THE DISCRIMINATION AND RECOGNITION OF SHAPES, ARE DISCUSSED ONLY IN SO FAR AS THE RELEVANT BEHAVIOUR IS AFFECTED BY ORIENTATION VARIABLES. GEOMETRICAL ILLUSIONS, FIGURAL AFTER-EFFECTS, AND JUDGMENTS OF VISUAL ANGLE, LENGTH, DISTANCE, AND MOVEMENT ARE OMITTED.

CHAPTERS 2 TO 6 INTRODUCE THE FOUR MODALITIES MOST CONCERNED IN HUMAN SPATIAL ORIENTATION. THE TACTILE MODALITY HAS BEEN OMITTED, AS ITS ROLE IN ORIENTATION IS OF MINOR IMPORTANCE. THESE CHAPTERS, WHILE PROVIDING AN UP-TO-DATE AND FAIRLY DETAILED REVIEW OF PRESENT-DAY KNOWLEDGE, ARE BY NO MEANS COMPREHENSIVE. CHAPTERS 7 TO 15 BEAR ON THE CENTRAL TOPIC OF THE BOOK. THEY ARE INTENDED TO COVER THE LITERATURE COMPREHENSIVELY, EITHER DIRECTLY OR BY REFERENCE TO EXISTING REVIEWS. THE FINAL CHAPTER IS A REVIEW OF MATERIAL ON ORIENTATION IN ZERO-G CONDITIONS. THIS MATERIAL, WHILE NOT CLASSIFIED AS SECRET, IS NOT GENERALLY AVAILABLE. WE CANNOT CLAIM THAT THE CHAPTER IS COMPREHENSIVE, FOR MUCH MATERIAL HAS NOT BEEN AVAILABLE.

HUDDESTON, J.F. INTER-SUBJECT DIFFERENCES IN MANUAL FLIGHT CONTROL. RAF INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH, HANTS, IAM SCIENTIFIC MEMORANDUM 68, OCT. 1965.

* ABSTRACT *

A BIBLIOGRAPHY IS PRESENTED, WITH SUMMARIES, OF THE LIMITED RESEARCH WORK AVAILABLE WHICH RELATES TO INTER-SUBJECT DIFFERENCES IN FLIGHT CONTROL ACTIVITY. THE FACT THAT INDIVIDUALS DO DIFFER IN THE STRATEGIES WITH WHICH THEY USE AN AIRCRAFT CONTROL IS SEEN AS HAVING POTENTIAL IMPLICATIONS FOR THEORIES OF SELECTION AND TRAINING, PERSONALITY, OPERATOR LOADING, MAN-MACHINE INTEGRATION, AND HUMAN TRANSFER FUNCTION ANALYSIS. SOME VERY TENTATIVE HYPOTHESES ARE ERECTED, RELATING TO PRESUMED INDIVIDUAL DIFFERENCES IN PERCEPTUAL DATA SAMPLING AND DECISION MODELLING SKILLS. IT IS APPARENT THAT MANUAL TRACKING IS A FUNCTION OF A LARGE NUMBER OF FACTORS, SOME OF WHICH CAN VARY BETWEEN INDIVIDUALS IN A POORLY UNDERSTOOD WAY, AND ONLY SOME OF WHICH ARE EASILY AMENABLE TO EXPERIMENTAL CONTROL.

HUDDESTON, H.F. COCKPIT MOTION REQUIREMENTS FOR FLIGHT SIMULATION. TECHNICAL REPORT (RAF INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH, HANTS. IAM REPORT 363, JAN. 1966.

* ABSTRACT *

FROM A REVIEW OF AVAILABLE LITERATURE, LARGELY AMERICAN IN ORIGIN, IT IS APPARENT THAT SOME ASPECTS OF BOTH THE TRANSFER OF AIRCREW TRAINING AND THE APPLICABILITY OF RESEARCH DATA CAN BE INFLUENCED BY THE COCKPIT DYNAMICS OF THE SIMULATOR ON WHICH THE WORK IS DONE. TO JUDGE SIMPLY BY THE VOLUME OF PUBLISHED WORK, PITCH AND ROLL ACCELERATIONS WOULD GENERALLY APPEAR TO BE OF PRIME IMPORTANCE, HEAVE ACCELERATIONS COMING A NEAR THIRD. IT IS EMPHASIZED, HOWEVER, THAT INSUFFICIENT FUNDAMENTAL INFORMATION IS AVAILABLE DESCRIBING EITHER HOW MAN COMBINES VARIOUS SENSATIONS INTO A PERCEPTION OF MOTION, OR HOW BEST MOTION PERCEPTIONS INDISTINGUISHABLE FROM THOSE IN FLIGHT CAN BE PRODUCED BY SIMULATION. THUS IT IS NOT, AT PRESENT, POSSIBLE TO DESIGN A MOTION PLATFORM FROM FIRST PRINCIPLES TO FULFIL A SPECIFIED CREW TRAINING OR HUMAN FACTORS RESEARCH REQUIREMENT, ALTHOUGH SENSIBLE APPROXIMATIONS ARE BEING MADE EMPIRICALLY FOR SOME APPLICATIONS.

HUDDESTON, H.F. AND ROLFE, J.M. BEHAVIORAL FACTORS INFLUENCING THE USE OF FLIGHT SIMULATORS FOR TRAINING. APPLIED ERGONOMICS, 1971, 2, 141-148.

* ABSTRACT *

ABSTRACT (OF INFORMATION RELATIVE TO MOTION)
 PROBABLY VESTIBULAR AND KINAESTHETIC CUES FOLLOW IN IMPORTANCE
 AFTER VISION AS FAR AS THE FLYING TASK IS CONCERNED. SINCE ONE
 EVALUATIVE REVIEW OF MOTION (HUDDLESTON 1966) THERE HAVE BEEN
 SOME 5-10 DEFENSIBLE PAPERS PER YEAR, DEPENDING ON ONE'S
 CRITERIA FOR INCLUSION. FEW WORKERS NOW NEED CONVINCING THAT
 WHOLE-BODY MOTION IS IMPORTANT, BUT THERE STILL SEEMS TO BE A
 TOTAL ABSENCE OF WORK ON MULTI-AXIS ABSOLUTE THRESHOLDS OR ON
 DIFFERENTIAL THRESHOLDS OF ANY KIND. ANOTHER AREA OF
 RESEARCH WHICH NEEDS MORE ATTENTION IS JUST WHAT THE OPERATOR
 DOES IN FLIGHT.

WITHOUT MOTION, EXPERIENCED PILOTS ARE OFTEN ABLE TO ACHIEVE A
 LEVEL OF PERFORMANCE WHICH IS PERFECTLY ACCEPTABLE, BUT AN
 EXAMINATION OF THEIR CONTROL BEHAVIOR SHOWS THAT THEIR
 PERFORMANCE IS ACHIEVED USING A STRATEGY ENTIRELY DIFFERENT TO
 THAT UTILIZED IN A DYNAMIC ENVIRONMENT. IT IS ALSO POSSIBLE TO
 ARGUE FROM COMPARATIVE STUDIES OF THE SAME PILOT'S RESPONSE IN
 FLIGHT AND IN A SIMULATOR WITH AND WITHOUT MOTION CUES (ROLFE,
 HAMMERTON-FRASER, POULTER, AND SMITH, 1968) THAT THE PRESENCE
 OF COCKPIT MOTION PRODUCES PATTERNS OF CONTROL RESPONSE MORE
 CLOSELY RELATED TO THOSE EMPLOYED IN FLIGHT. THIS LATTER
 FINDING IS SUPPORTED BY OTHER RESEARCH (FEDDERSEN, 1962;
 TREMBLEY, BROWN, AND FUTTERWEIT, 1964; STAPLES, 1970).

MEYER 1967 ASKED PILOTS CONVERTING TO THE DC-8 AIRCRAFT TO
 ASSESS WHICH FEATURES OF THE SIMULATOR AFFECTED ITS VALUE AS A
 TRAINING DEVICE AND RELATE THEM TO PARTICULAR ASPECTS OF THE
 TRAINING PROGRAMME. THE FACTOR MOST COMMENTED UPON INCLUDED
 ACCELERATION FORCES, VIBRATION, ROLL, PITCH AND YAW MOTION.

HUFF, E.M. AND NAGEL, D.C. PSYCHOLOGICAL ASPECTS OF AERONAUTI-
 CAL FLIGHT SIMULATION, 'AMERICAN PSYCHOLOGIST', MAR. 1975,
 426-438.

* ABSTRACT *

A BROAD REVIEW ARTICLE COVERING MANY ASPECTS OF FLIGHT
 SIMULATION INCLUDING VISUAL SCENE ATTACHMENTS AND SIMULATOR
 MOTION SYSTEMS. THE DISCUSSION IS AIMED PRIMARILY AT RESEARCH
 SIMULATORS AND RAISES A NUMBER OF QUESTIONS CONCERNING
 NECESSARY AND SUFFICIENT SIMULATOR FIDELITY FOR VARIOUS
 AERONAUTICAL APPLICATIONS. CHARACTERISTICS OF MANY OF THE MOST
 ADVANCED MOTION-BASED RESEARCH SIMULATORS ARE LISTED IN A
 TABLE.

IN A SECTION ON NEW TECHNIQUES, THE AUTHOR PROPOSES THAT THE
 USE OF THE THEORY OF SIGNAL DETECTABILITY AND RELATED MODELS TO
 OBTAIN INDEXES OF PERCEPTUAL FIDELITY, COMPARING MEASURES
 TAKEN IN SIMULATORS AND IN FLIGHT CAN CONTRIBUTE TO THE
 DEVELOPMENT OF SIMULATION AS A SCIENCE.

HUFFMAN, W.E. - FLIGHT TRAINER
PATENT NO. 1,944,180
FILED NOV. 17, 1932 GRANTED JAN. 23, 1934

NO ABSTRACT

HUNTER, G.S. 'ATA URGES ADVANCES IN FLIGHT SIMULATORS'. 'AVIA-
TION WEEK AND SPACE TECHNOLOGY'. MARCH 4, 1968.

* ABSTRACT *
ABSTRACT (MOTION RELEVANT INFORMATION)

BOTH THE AIRLINES AND AIRCRAFT MANUFACTURERS FURTHER AGREE THAT FLIGHT SIMULATORS SHOULD BE ABLE TO DUPLICATE THE PILOTS SENSATIONS OR KINESTHESIA OF AT LEAST THE INITIAL ACCELERATIONS AND CHANGES OF AIRCRAFT ATTITUDE. THE RANGE CONSISTS OF ANGULAR AND LINEAR DISPLACEMENTS IN THE SIX DEGREES OF FREEDOM POSSIBLE IN FLIGHT DYNAMICS, INCLUDING PITCH, ROLL, YAW, VERTICAL HEAVE, LONGITUDINAL SURGE AND LATERAL TRANSLATION.

SUCH COMPLETE MOVING-BASE MECHANICAL SIMULATION IS NOT YET AVAILABLE. BUT THE NEW GENERATION OF 747 SIMULATORS BEING DESIGNED BY CONDUCTION AND LINK ARE ALL BEING DESIGNED WITH SIX DEGREE SYSTEMS.

SIMULATOR USERS ALSO FEEL THAT THE ADDITIONAL DYNAMIC EFFECTS OF SIZABLE AIRFRAME DEFLECTIONS POSSIBLE IN VERY LARGE AIRCRAFT DUE TO STRUCTURAL FLEXIBILITIES AND INERTIAL LAGS AWAY FROM THE CENTER OF GRAVITY ALSO SHOULD BE ACCOUNTED FOR IF OPERATIONAL REALITY IS TO BE REPRODUCED FULLY. THIS POSSIBLY COULD BE ACCOMPLISHED BY DIGITAL INCORPORATION OF SUCH MOTIONS INTO THE SIMULATOR SYSTEM AS ADDITIONAL DEGREES OF FREEDOM.

ALTHOUGH THE LATERAL AND YAW MOTIONS OF AN AIRCRAFT CAN TO SOME DEGREE BE USED INTERCHANGEABLY FOR SIMULATION PURPOSES, MANUFACTURERS CONSIDER THE COMPLETE SIX-DEGREES-OF-FREEDOM SYSTEMS ACTUALLY THE EASIER TO PRODUCE AS A DESIGN CONCEPT. MOREOVER, THE LATERAL OR SIDE ACCELERATIONS PROVIDE THE PILOT WITH A USEFUL ADDITIONAL SEAT-OF-THE-PANTS WARNING FEEL OF LOSS OF AN ENGINE THAT CAN BE CRUCIAL ON TAKEOFFS.

HUNTER, S., GUNDRY, A.J. AND ROLFE, J.M. HUMAN FACTORS TOPICS IN FLIGHT SIMULATION: AN ANNOTATED BIBLIOGRAPHY. AGARD REPORT 656, ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT, NATO, JUNE 1977.

* ABSTRACT *

THIS BIBLIOGRAPHY CONTAINS 504 REFERENCES, WITH SUMMARIES, TO REPORTS CONCERNED WITH HUMAN FACTORS TOPICS IN FLIGHT SIMULATION. REPORTS DEALING SOLELY WITH THE ENGINEERING ASPECTS OF FLIGHT SIMULATION HAVE BEEN EXCLUDED, UNLESS THEY CONTAIN ITEMS OF HUMAN FACTORS INTEREST. THE BIBLIOGRAPHY, COVERING THE YEARS 1940 TO 1976, IS MAINLY COMPRISED OF ENGLISH-LANGUAGE REPORTS AND CONTAINS NO REFERENCE TO CLASSIFIED MATERIAL. THIS REPORT WAS PREPARED AT THE REQUEST OF THE AEROSPACE MEDICAL PANEL OF AGARD.

FUTTER, W.T. - PILOT TRAINER
PATENT NO. 2,409,938
FILED JULY 24, 1942 GRANTED OCT. 22, 1946

NO ABSTRACT

FUTTON, D.F., BURKE, D., ENGLEHART, J.D., WILSON, J.M., REMAGLIA, F.J., AND SCHNEIDER, A.J. AIR-TO-GROUND VISUAL SIMULATION DEMONSTRATION. FINAL REPORT, VOL. 1, PROJECT 2235, AERONAUTICAL SYSTEMS DIVISION, SIMULATOR SP8, WRIGHT PATTERSON AFB, OH. OCT. 1976.

* ABSTRACT *

THIS PROJECT WAS THE RESULT OF INCREASED INTEREST ON THE FEASIBILITY OF VISUALLY SIMULATING ENVIRONMENTS FOR THE FIGHTER/ATTACK MISSION. FOUR SIMULATORS WERE EVALUATED: (1) ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT), (2) LARGE AMPLITUDE MULTI-MODE AEROSPACE RESEARCH SIMULATOR (LAMARS), (3) SIMULATOR FOR AIR-TO-AIR COMBAT (SAAC/F-4E NO. 18) AND (4) DEVICE 2B35 (VISUAL SYSTEM).

IN ADDITION TO THE EVALUATION OF VISUAL SYSTEMS, EACH PILOT WAS GIVEN AN EQUAL AMOUNT OF TASK PERFORMANCE WITH AND WITHOUT MOTION.

HYDE, A.S. MAN-RATED CENTRIFUGES: A NATIONAL SURVEY WITH DESIGN CONSIDERATIONS AND RECOMMENDATIONS FOR FUTURE DEVICES. AEROSPACE MEDICAL RESEARCH LABORATORIES, WRIGHT-PATTERSON AIR FORCE BASE, OHIO, AMRL MEMORANDUM B-55, SEPTEMBER 1963, 27 PP, AD 419 380.

* ABSTRACT *

IT HAS BEEN THE THESIS OF THIS MEMORANDUM REPORT THAT THE NEED FOR MAN-RATED CENTRIFUGES WILL CONTINUE TO INCREASE, THAT MORE

DEVICES OF THIS TYPE WILL BE PROPOSED AND BUILT WITHIN THE NEXT DECADE, AND THAT PERFORMANCE (AND COST) OF THESE DEVICES WILL ALSO CONTINUE TO INCREASE. CATEGORIES OF USE OF MAN-RATED CENTRIFUGES HAVE BEEN PRESENTED AND COMPARED TO OUR NATIONAL CAPABILITIES: OUR CAPABILITIES WERE FOUND TO BE LESS THAN OUR NEEDS. IN ORDER TO TRANSMIT EXPERIENCE GAINED BY THE AUTHOR IN ESTABLISHING SPECIFICATIONS FOR MAN-RATED CENTRIFUGES, INFORMATION WAS OFFERED RELATING TO MAJOR TRADE-OFFS THAT INFLUENCE FINAL DESIGN CONFIGURATION, COST AND USEFULNESS OF THESE DEVICES.

INCE, F. WILLIGES, R.C. AND ROSCOE, S.N.
AIRCRAFT SIMULATOR MOTION AND THE ORDER OF MERIT OF FLIGHT ATTITUDE AND STEERING GUIDANCE DISPLAYS. IN 'PROCEEDINGS HUMAN FACTORS SOCIETY 17TH ANNUAL MEETING', WASHINGTON, D.C. OCTOBER 16-18 1973, P.256-264.

* ABSTRACT *

INVESTIGATION OF THE EFFECTS OF VARIATIONS IN FLIGHT SIMULATOR MOTION DYNAMICS UPON THE ORDER OF MERIT OF A FAMILY OF FLIGHT DISPLAYS. THE RESULTS INDICATE THAT THE OUTCOME OF HUMAN ENGINEERING EXPERIMENTS IN SIMULATORS CAN DEPEND UPON THE MOTION SYSTEM EMPLOYED. IN THE EXPERIMENTS PERFORMED, ONLY TWO DEGREES OF MOTION FREEDOM WERE AVAILABLE FOR EXPERIMENTAL MANIPULATION. NEVERTHELESS, RESULTS OBTAINED FOR VARIOUS FLIGHT TASKS WERE SUFFICIENTLY CLEAR TO ALLOW THE CONCLUSION THAT MOTION SYSTEMS THAT INTRODUCE GRAVITATIONAL CUES NOT PRESENT IN FLIGHT CAN BE AS DAMAGING TO THE VALIDITY OF AN EXPERIMENT AS THE ABSENCE OF ACCELERATION CUES.

INCE, F. WILLIGES, R.C. AND ROSCOE, S.N.
AIRCRAFT SIMULATOR MOTION AND THE ORDER OF MERIT OF FLIGHT ATTITUDE AND STEERING GUIDANCE DISPLAYS. UNIVERSITY OF ILLINOIS AVIATION RESEARCH LAB. PRESENTED AT THE '17TH ANNUAL MEETING OF THE HUMAN FACTORS SOCIETY', WASHINGTON, D.C. 16-18 OCTOBER 1973. (ALSO 'HUMAN FACTORS', 1975, 17, 388-400)

* ABSTRACT *

TWENTY-FOUR NONPILOT, VOLUNTEER SUBJECTS WERE TESTED ON THREE FLIGHT TASKS WHILE FLYING FOUR BASIC AIRCRAFT ATTITUDE PRESENTATIONS (MOVING HORIZON, MOVING AIRCRAFT, FREQUENCY-SEPARATED AND KINALOG) IN A LIGHT TWIN-ENGINE AIRCRAFT SIMULATOR PROVIDING THREE LEVELS OF MOTION CUES (NO MOTION, STANDARD CAT-2 MOTION AND WASHOUT MOTION). THE FLIGHT TASKS INVOLVED CONFLICTING VISUAL AND VESTIBULAR CUES AND INCLUDED DISTURBED ATTITUDE TRACKING, COMMAND FLIGHT PATH TRACKING IN BOTH PURSUIT AND COMPENSATORY MODES, AND A SERIES OF RECOVERY TRIALS FROM DISCRETE UNKNOWN ATTITUDES. TO

PROVIDE A BASIS FOR COMPARISON, THE PRESENT SIMULATOR STUDY CLOSELY REPLICATED THE PROCEDURES USED IN THE ROSCOE & WILLIGES (1973) FLIGHT EXPERIMENT. THE FREQUENCY-SEPARATED DISPLAY PROVIDED PERFORMANCES AT LEAST EQUIVALENT AND IN SOME CASES SUPERIOR TO THOSE OBTAINED WITH THE CONVENTIONAL MOVING HORIZON DISPLAY. EITHER TYPE OF SIMULATOR MOTION RESULTED IN BETTER DISTURBED ATTITUDE TRACKING PERFORMANCE THAN NO MOTION, AND WASHOUT MOTION PROVIDED STEREOTYPED CONTROL RESPONSES IN RECOVERY FROM UNKNOWN ATTITUDES MOST CLOSELY CORRESPONDING TO THOSE OBTAINED IN FLIGHT. IT WAS CONCLUDED THAT CARE MUST BE USED IN GENERALIZING SIMULATOR RESULTS TO FLIGHT PERFORMANCE WHEN NO PHYSICAL MOTION CUES OR INAPPROPRIATE ONES ARE PRESENT IN THE SIMULATOR.

INCE, F. WILLIGES, R.C. AND ROSCOE, S.N.
AIRCRAFT SIMULATOR MOTION AND THE ORDER OF MERIT OF FLIGHT ATTITUDE AND STEERING GUIDANCE DISPLAYS. 'HUMAN FACTORS', VOL. 17, P. 388-400 AUGUST 1975.

* ABSTRACT *

NONPILOT SUBJECTS WERE TESTED IN VARIOUS SIMULATED FLIGHT TASKS IN ORDER TO PROVIDE INFORMATION CONCERNING BOTH THE FREQUENCY-SEPARATED DISPLAY PRINCIPLE AND THE EFFECTS OF SIMULATED MOTION CUES. THE FREQUENCY-SEPARATED DISPLAY TESTED LED TO REDUCTIONS IN DISTURBED ATTITUDE TRACKING ERRORS. IN THE INCIDENCE OF CONTROL REVERSALS, AND IN RECOVERY TIMES TO LEVEL FLIGHT FROM UNKNOWN ATTITUDES, TWO MODES OF SIMULATOR MOTION (STEADY BANK ANGLE AND CONSTANT ROLL) WERE TESTED AND BOTH FACILITATED DISTURBED ATTITUDE TRACKING PERFORMANCE. BUT INAPPROPRIATE GRAVITATIONAL FORCES CREATED BY SUSTAINED BANKING MOTION INTERFERED WITH COMMAND FLIGHT PATH TRACKING. WASHOUT MOTION (CONSTANT ROLL) GAVE RESULTS MOST CLOSELY APPROXIMATING FLIGHT DATA. THE PRESENT STUDY WAS BASED IN FORMAT ON THE PREVIOUS INVESTIGATION BY ROSCOE AND WILLIGES (1975). IT IS CONCLUDED THAT CAUTION MUST BE EXERCISED IN GENERALIZING EXPERIMENTAL FINDINGS IN SIMULATORS WITH NO COCKPIT MOTION, OR WITH INAPPROPRIATE ACCELERATION CUES, TO FLIGHT PERFORMANCE PREDICTION.

IRISH, P.A., III, & BROWN, J.E. SUBJECTIVE MOTION DISCRIMINATION IN THE SIMULATOR FOR AIR-TO-AIR COMBAT. AFHRL-TR-78-26. WILLIAMS AFB, AZ: FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, AUGUST 1978.

* ABSTRACT *

THE OBJECTIVES OF THIS STUDY WERE TO: (A) ACQUIRE SUBJECTIVE INFORMATION ON THE ABILITY OF PILOTS TO PERCEPTUALLY DIFFERENTIATE BETWEEN SELECTED CONDITIONS OF MOTION CUEING IN THE SIMULATOR

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FOR AIR-TO-AIR COMBAT (SAAC) AND (B) PREPARE THE INITIAL FRAME-
WORK FOR FOLLOW-ON STUDIES DESIGNED TO DETERMINE THE CONTRIBU-
TIONS OF MOTION CUEING TO PERFORMANCE AND TO TRAINING IN THE
SAAC.

IN RESPONSE TO A STATED RESEARCH REQUIREMENT WITHIN THE FOLLOW-
ON OPERATIONAL TEST AND EVALUATION PLAN OF THE SIMULATOR FOR
AIR-TO-AIR COMBAT, A RESEARCH PROGRAM WAS DEVELOPED IN SEPTEMBER
1975 TO INVESTIGATE THE EFFECTIVENESS OF THE PLATFORM MOTION, G-
SEAT, AND G-SLIT SYSTEMS PRESENT ON THE SAAC. THE FIRST STAGE IN
THIS RESEARCH PLAN WAS TO EXPERIMENTALLY EXAMINE PILOTS' ABILI-
TIES TO SUBJECTIVELY DISCRIMINATE VARIOUS MOTION-CUEING CONDI-
TIONS WHILE FLYING MANEUVERS IN THE SAAC. THIS INVESTIGATION WAS
TO BE CONDUCTED PRIOR TO THE DEVELOPMENT AND IMPLEMENTATION OF
AUTOMATED PERFORMANCE MEASUREMENT SCORING ROUTINES IN THE
SIMULATOR.

THE RESULTS OF THIS STUDY STRONGLY SUGGEST THAT ALTERNATIVE
METHODS TO THE SUBJECTIVE PILOT RATING TECHNIQUE BE EMPLOYED
WHEN ATTEMPTING TO ESTABLISH PERCEPTUAL DIFFERENCES CONCERNING
MOTION-CUEING DEVICES IN THE VISUALLY EQUIPPED FLIGHT SIMULATOR.
THE INABILITY OF BOTH GROUPS OF PILOTS TO DETECT CHANGES IN THE
STATUS OF THE G-SEAT AND PLATFORM MOTION SYSTEM MAY HAVE BEEN
DUE TO A NUMBER OF REASONS. THE RATING SCALES MAY HAVE BEEN AN
INSENSITIVE MEASUREMENT TOOL. THE PILOTS MAY HAVE BECOME INSEN-
SITIVE TO THE CHANGES, BECAUSE OF EXCESSIVE TASK DIFFICULTY,
VISUAL DISPLAY DOMINANCE, OR ACTUAL INEFFECTIVE MOTION CUEING.
DUE TO THE POOR RELIABILITY OF THE DATA, NO CLEAR ANSWER IS
AVAILABLE.

IRISH, P.A., III, AND BUCKLAND, G.H. EFFECTS OF PLATFORM MO-
TION, VISUAL AND G-SEAT FACTORS UPON EXPERIENCED PILOT PERFORM-
ANCE IN THE FLIGHT SIMULATOR. AFHRL-TR-78-9. WILLIAMS AFB, AZ:
FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY,
JUNE 1978.

* ABSTRACT *

THE OBJECTIVES OF THIS STUDY WERE: (A) TO EMPIRICALLY ASSESS THE
PERFORMANCE OF EXPERIENCED T-37 PILOTS IN THE ADVANCED SIMULATOR
FOR PILOT TRAINING (ASPT) UNDER VARYING PLATFORM MOTION, G-SEAT,
FIELD-OF-VIEW (FBV) AND CEILING/VISIBILITY CONDITIONS; (B) TO
FURTHER EXPLORE THE PROMINENT MAIN AND INTERACTIVE EFFECTS WHICH
WERE REPORTED IN AN EARLIER STUDY OF THESE VARIABLES (AFHRL-TR-
77-13); (C) TO EXTEND THE INVESTIGATION OF THESE VARIABLES INTO
MANEUVERS REPRESENTATIVE OF A MORE DYNAMIC FLIGHT REGIME; AND
(D) TO ACQUIRE ADDITIONAL INFORMATION REGARDING THE RELATION-
SHIPS BETWEEN SYSTEM OUTPUT MEASURES AND PILOT INPUT MEASURES,
AS MEASURED BY THE AUTOMATED MEASUREMENT CAPABILITY OF THE ASPT.
CONCLUSIONS

1. EXPERT PILOTS TEND TO PERFORM BETTER WITH WIDER VISUAL
FIELDS-OF-VIEW AND WITHOUT PLATFORM MOTION FOR THE MANEUVERS

INVESTIGATED IN THIS STUDY.

2. THE PRESENCE OR ABSENCE OF THE G-SEAT VARIABLE DID NOT APPEAR TO EFFECT ANY CHANGES IN PILOT PERFORMANCE.

3. ALTHOUGH THE SIMULATOR CONFIGURATION VARIABLES SUCH AS MOTION AND FIELD-OF-VIEW CAUSE CHANGES IN PILOT PERFORMANCE, THESE EFFECTS ARE OFTEN MANIFESTED AS CHANGES IN CONTROL BEHAVIOR RATHER THAN CHANGES IN VEHICLE PERFORMANCE. ALSO THE INTERACTION EFFECTS BETWEEN SUCH CONFIGURATION VARIABLES ARE RELATIVELY INSIGNIFICANT IN COMPARISON TO THEIR MAIN EFFECTS.

IRISH, P.A. III, GRUNZKE, P.M., GRAY, T.H., AND WATERS, B.K. THE EFFECTS OF SYSTEM AND ENVIRONMENTAL FACTORS UPON EXPERIENCED PILOT PERFORMANCE IN THE ADVANCED SIMULATOR FOR PILOT TRAINING, FLYING TRAINING DIVISION, 'AIR FORCE HUMAN RESOURCES LABORATORY REPORT' AFHRL-TR-77-13, WILLIAMS AIR FORCE BASE, ARIZONA, APRIL 1977.

* ABSTRACT *

THE OBJECTIVES OF THE STUDY WERE:

(A) TO ASSESS THE RELATIVE CONTRIBUTION OF PLATFORM MOTION, G-SEAT AND VISUAL FACTORS TO PILOT PERFORMANCE IN THE ADVANCED SIMULATOR FOR PILOT TRAINING (ASPT);

(B) TO ACQUIRE INFORMATION ON THE RELATIONSHIPS BETWEEN SYSTEM OUTPUT AND PILOT INPUT MEASURES AS COLLECTED IN THE ASPT; AND

(C) TO EVALUATE THE UTILITY OF ECONOMICAL MULTIFACTOR DESIGNS FOR FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY (AFHRL/FT) RESEARCH IN FLIGHT SIMULATION. THREE EXPERIENCED T-37 PILOTS FLEW FIVE MANEUVERS IN THE ASPT UNDER COMBINATIONS OF THE INDEPENDENT VARIABLES: PLATFORM MOTION, G-SEAT, FIELD OF VIEW, TURBULENCE, WIND AND CEILING/VISIBILITY. AUTOMATED PERFORMANCE MEASURES BASED ON SYSTEM PARAMETERS, PILOT INPUTS AND DERIVED SCORES WERE COLLECTED AND ANALYZED. BOTH MAIN AND INTERACTIVE EFFECTS OF THE INDEPENDENT VARIABLES WERE FOUND FOR A MAJORITY OF THE MANEUVERS. A DISCUSSION OF THE UTILITY OF THE ECONOMICAL MULTIFACTOR DESIGNS IS INCLUDED. ADDITIONALLY, IMPLICATIONS FOR DETERMINING THE DIRECTION OF FUTURE STUDIES ARE DISCUSSED.

JACOBS, R.S. SIMULATOR COCKPIT MOTION AND THE TRANSFER OF INITIAL FLIGHT TRAINING. UNIV. OF ILLINOIS (SAVOY AVIATION RESEARCH LAB.); URBANA-CHAMPAIGN, REPORT ARL-76-8/AFBSR-77-0880 TR, JUNE 1976.

* ABSTRACT *

TRANSFER OF FLIGHT TRAINING FROM A SINGER-LINK GAT-2 TRAINING

AD-A061 687 NAVAL TRAINING EQUIPMENT CENTER ORLANDO FLA
MOTION IN FLIGHT SIMULATION: AN ANNOTATED BIBLIOGRAPHY. (U)
JUL 78 J A PUIO, W T HARRIS, & L RICARD
UNCLASSIFIED NAVTRAEQUIPC-IH-296

NAVAL TRAINING EQUIPMENT CENTER ORLANDO FLA
MOTION IN FLIGHT SIMULATION: AN ANNOTATED BIBLIOGRAPHY. (U)
JUL 78 J A PUIG, W T HARRIS, G L RICARD

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SIMULATOR, MODIFIED TO APPROXIMATE A COUNTERPART PIPER CHEROKEE ARROW AIRPLANE, WAS MEASURED FOR INDEPENDENT GROUPS OF NINE FLIGHT-NAIVE SUBJECTS, EACH TRAINED IN ONE OF THREE SIMULATOR COCKPIT MOTION CONDITIONS: NORMAL WASHOUT MOTION IN BANK WITH SUSTAINED PITCH ANGLES, WASHOUT BANKING MOTION IN WHICH THE DIRECTION OF MOTION RELATIVE TO THAT OF THE SIMULATED AIRPLANE WAS RANDOMLY REVERSED 50% OF THE TIME AS THE CAB PASSED THROUGH A WINGS-LEVEL ATTITUDE, AND A FIXED-BASE CONDITION. SUBJECTS RECEIVED A PREDETERMINED FIXED AMOUNT OF PRACTICE IN THE SIMULATOR ON EACH OF 11 FLIGHT MANEUVERS DRAWN FROM THE PRIVATE PILOT FLIGHT CURRICULUM. TRANSFER PERFORMANCE MEASURES, INCLUDING FLIGHT TIME AND TRIALS TO FAA PERFORMANCE CRITERIA AND TOTAL ERRORS MADE IN THE PROCESS SHOWED RELIABLE TRANSFER FOR ALL GROUPS WITH DIFFERENTIAL TRANSFER EFFECTS AND COST-EFFECTIVENESS IMPLICATIONS DEPENDING UPON THE TYPE OF SIMULATOR MOTION. AN APTITUDE ESTIMATOR MEASURE AND THE ANALYSIS OF CO-VARIANCE TECHNIQUE PROVIDED INCREASED DISCRIMINATION AMONG GROUPS IN THE PRESENCE OF CONSIDERABLE INDIVIDUAL VARIATION IN PERFORMANCE WITHIN TREATMENT CONDITIONS.

JACOBS, R.S. AND ROSCOE, S.N.
SIMULATOR COCKPIT MOTION AND THE TRANSFER OF INITIAL FLIGHT TRAINING. IN 'PROCEEDINGS 8TH NTEC INDUSTRY CONFERENCE', 18-20 NOV. 1975, PP. 113-122.
(ALSO ARL-75-18/AFOSR-75-8, 1975)

* ABSTRACT *

TRANSFER OF FLIGHT TRAINING FROM A SINGER-LINK GAT-2 TRAINING SIMULATOR, MODIFIED TO APPROXIMATE A COUNTERPART PIPER CHEROKEE ARROW AIRPLANE, WAS MEASURED FOR INDEPENDENT GROUPS OF NINE FLIGHT-NAIVE SUBJECTS, EACH TRAINED IN ONE OF THREE SIMULATOR COCKPIT MOTION CONDITIONS: NORMAL WASHOUT MOTION IN BANK WITH SUSTAINED PITCH ANGLES, WASHOUT BANKING MOTION IN WHICH THE DIRECTION OF MOTION RELATIVE TO THAT OF THE SIMULATED AIRPLANE WAS RANDOMLY REVERSED 50% OF THE TIME AS THE CAB PASSED THROUGH A WINGS-LEVEL ATTITUDE, AND A FIXED-BASE CONDITION. SUBJECTS RECEIVED A PREDETERMINED FIXED AMOUNT OF PRACTICE IN SIMULATOR ON EACH OF 11 FLIGHT MANEUVERS DRAWN FROM THE PRIVATE PILOT FLIGHT CURRICULUM. TRANSFER PERFORMANCE MEASURES, INCLUDING FLIGHT TIME AND TRIALS TO FAA PERFORMANCE CRITERIA AND TOTAL ERRORS MADE IN THE PROCESS SHOWED RELIABLE TRANSFER FOR ALL GROUPS WITH DIFFERENTIAL TRANSFER EFFECTS AND COST-EFFECTIVENESS IMPLICATIONS DEPENDING UPON THE TYPE OF SIMULATOR MOTION.

JACOBS, R.S., WILLIGES, R.C. AND ROSCOE, S.N. 'SIMULATOR MOTION AS A FACTOR IN FLIGHT-DIRECTOR DISPLAY EVALUATION'. 'HUMAN FACTORS', 1973, 15, 569-582.

* ABSTRACT *

THE RESULTS OF RESEARCH CONDUCTED IN GROUND-BASED FLIGHT SIMULATORS MUST BE INTERPRETED WITH CARE IN VIEW OF THE POTENTIAL EFFECTS OF DIFFERENCES BETWEEN THE SIMULATED AND ACTUAL FLIGHT ENVIRONMENTS. A STUDY COMPARING VARIOUS FLIGHT-DIRECTOR DISPLAYS IN A MOVING-BASE SIMULATOR WAS REPLICATED WITHOUT MOTION. SIGNIFICANTLY DIFFERENT RESULTS OCCURRED AS A FUNCTION OF THE PRESENCE OR ABSENCE OF MOTION. IMPLICATIONS OF THESE RESULTS RAISE DOUBT CONCERNING THE VALIDITY OF FINDINGS FROM SIMULATOR EXPERIMENTS IN WHICH WHOLE-BODY ACCELERATION CUES MIGHT BE A FACTOR.

JACOBSON, I.D. AND JOSHI, D.S.
MODELING ATMOSPHERIC TURBULENCE FOR A MOTION-BASED SIMULATOR.
SCHOOL OF ENGINEERING AND APPLIED SCIENCE, UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, VIRGINIA FOR NASA. STATUS REPORT NASA
GRANT NO. NGR 47-005/028, OCTOBER 1975

* ABSTRACT *

THE BACKGROUND INFORMATION IN ESTABLISHING SEVERAL PROPOSED ATMOSPHERIC TURBULENCE MODELS FOR USE ON MOTION BASED AIRCRAFT SIMULATORS WAS DOCUMENTED. A SPECIFIC MODEL WAS PROPOSED WHICH IN ADDITION TO VARYING TURBULENCE INTENSITY (RMS VELOCITY), VARIES THE ATMOSPHERIC TURBULENCE SCALE LENGTH TO ACHIEVE COMPATIBILITY WITH REAL ATMOSPHERIC TURBULENCE. WITH A SUITABLE COMBINATION OF SCALE LENGTH AND INTENSITY DISTRIBUTION THE MODEL WILL SIMULATE VARIOUS ATMOSPHERIC CONDITIONS CHARACTERIZED BY ALTITUDE, STABILITY AND TERRAIN. THE MODEL IS MECHANIZED TO BE INCLUDED IN A FLIGHT SIMULATOR EXPERIMENT IN ORDER TO DETERMINE TO WHAT EXTENT THE PILOTS ARE SENSITIVE TO CHANGES IN ATMOSPHERIC CONDITIONS AND THE REALISM OF THE MODEL. THE FOLLOWING TOPICS WERE COVERED - LITERATURE SURVEY, PRESENTLY USED TECHNIQUES, PROPOSED MODEL AND SIMULATION DETAILS.

JACOBSON, I.D., SCHULTZ, M.B. AND BLAKE, J.C. EFFECTS OF MOTION FREQUENCY SPECTRUM ON SUBJECTIVE COMFORT RESPONSE.
NASA CR-138883, 1973.

* ABSTRACT *

FOR THE MODELLING OF PASSENGER REACTION TO PRESENT AND FUTURE AIRCRAFT ENVIRONMENTS, SUBJECTIVE INFORMATION MAY BE GATHERED ON COMMERCIAL FLIGHTS. IN ADDITION, DETAILED ANALYSIS OF PARTICULAR ASPECTS OF REACTIONS TO THE ENVIRONMENT ARE BEST STUDIED IN A CONTROLLABLE EXPERIMENTAL SITUATION. FOR THIS, THE USE OF IN-FLIGHT AND GROUND BASED SIMULATORS IS SUGGESTED. IT IS SHOWN THAT THERE IS A REASONABLY HIGH PROBABILITY THAT THERE IS NO NEED FOR LOW FREQUENCY SIMULATION, I.E. THE FIDELITY OF ANY

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SIMULATION WHICH OMITTS THE VERY LOW FREQUENCY CONTENT WILL NOT YIELD RESULTS WHICH DIFFER SIGNIFICANTLY FROM THE REAL ENVIRONMENT AS AGAINST THOSE OBTAINED ON COMMERCIAL FLIGHTS.

JOHANSSON, GUNNAR, 'STUDIES ON MOTION AFTER-EFFECTS II'. REPORT #13. THE PSYCHOLOGICAL LABORATORY, THE UNIVERSITY OF STOCKHOLM, FEBRUARY 1955. 'PSYCHOL. BEIT.', 1960, 5, 81-92.

* ABSTRACT *

THE DURATION OF MOTION AFTEREFFECT AFTER SINGLE-STIMULATION (MAE) WAS INVESTIGATED AS A FUNCTION OF STIMULUS TIME AND OF EXTENSION OF PROXIMAL STIMULUS MOTION. 6 S'S TOOK PART IN THE INVESTIGATION. THE MAIN RESULTS WERE (A) MAE DURATION VARIES WITH CHANGES IN TIME-SPACE. (B) ACCORDING TO THE RESULTS OBTAINED FROM 5 S'S THE EQUATION $R=C \log S$ IS VALID FOR THIS RELATIONSHIP. (C) IT SEEMS PROBABLE THAT THE LENGTH OF PROXIMAL MOTION TRACK AND NOT THE DURATION OF MOTION SIMULATION IS THE MAIN ACTIVE STIMULUS FACTOR.

JOHNSON, F.I. SIMULATION AND TRAINING FACILITIES. 'ASTRONAUTICS AND AEROSPACE ENGINEERING', FEB. 1963.

* ABSTRACT *

THIS PAPER DISCUSSES THE FACILITIES FOR MANNED SPACEFLIGHT PROJECTS SUCH AS GEMINI AND APOLLO. OF PARTICULAR INTEREST TO MOTION SIMULATION IS THE FOLLOWING EXCERPT: 'ONLY ONE FACTOR ALLOWING APPRECIABLE COST REDUCTIONS CAN AFFECT THESE FLIGHT TRAINERS: THE ACTUAL PHYSICAL TRANSLATIONAL AND ROTATIONAL MOTIONS OF THE SPACECRAFT WILL NOT BE SIMULATED, EVEN AS WASHED OUT MOTION. THE JUSTIFICATION FOR THIS OMISSION IS BASED ON COMMENTS OF ALL THE ASTRONAUTS WHO HAVE FLOWN THE MERCURY SPACECRAFT. APPARENTLY, ROTATIONAL MOTIONS IN SPACE MORE NEARLY RESEMBLE A MOTIONLESS STATE THAN A ROTATING MOTION IN A 1-G ENVIRONMENT, INsofar AS BODY SENSATIONS ARE CONCERNED. AT ANY RATE, THE ASTRONAUTS REPORT THAT DISPLAY MOTIONS ALONE IN FIXED-BASE SIMULATORS CONSTITUTE A SURPRISINGLY GOOD APPROXIMATION OF COMBINED INSTRUMENT AND BODY MOVEMENTS UNDER WEIGHTLESSNESS IN SPACE. LINEAR ACCELERATIONS DURING LAUNCH AND RE-ENTRY CAN BE REPRODUCED SATISFACTORILY AS A PART-TASK ON THE CENTRIFUGE AND THEREFORE NEED NOT BE PROVIDED IN THE FLIGHT TRAINERS.'

JOHNSON, L.L. STUDY TO DETERMINE METHODS OF SIMULATING G EFFECTS, SUPPLEMENT 1. 'ARMOUR RESEARCH FOUNDATION OF ILLINOIS INSTITUTE OF TECHNOLOGY, FOR WRIGHT AIR DEVELOPMENT CENTER, AIR RESEARCH AND DEVELOPMENT COMMAND, UNITED STATES AIR FORCE,

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WRIGHT-PATTERSON AFB, OHIO. (WADC TECHNICAL NOTE) 58-314, AUGUST 1959.

* ABSTRACT *

AN EXPERIMENTAL VARIABLE-AREA INFLATABLE SEAT AND SHOULDER HARNESS WITH THE NECESSARY PNEUMATIC ACTUATORS FOR THE SIMULATION OF G FORCE WAS FABRICATED ON THE BASIS OF THE SYSTEM CONCEPT PRESENTED IN WADC TECHNICAL NOTE 58-134. A SPECIAL PNEUMATIC CONTROLLER WAS DEVELOPED. THE FABRICATION OF THE SYSTEM AND THE SUBSEQUENT TESTING IS BRIEFLY OUTLINED. THE SEAT IS DESCRIBED AND ILLUSTRATED BY NINE PHOTOGRAPHS. IT IS CONCLUDED THAT THE SYSTEM CONCEPT IS FEASIBLE AND THAT THE SIMULATED REACTIONS AND EFFECTS ARE QUITE ACCURATE AND REALISTIC.

JOHNSON, STEVEN L., KNIGHT, JAMES R., AND SUGARMAN, ROBERT C.
B-1 SYSTEMS APPROACH TO TRAINING, FINAL REPORT, SIMULATION TECHNOLOGY ASSESSMENT REPORT (STAR) REPORT: SAT-3
CALSPAN CORPORATION, P.O. BOX 235, BUFFALO, NEW YORK 14221
AERONAUTICAL SYSTEMS DIVISION, B-1 SYSTEMS PROJECT OFFICE,
WRIGHT-PATTERSON AIR FORCE BASE, OH 45433, JULY 1975

* ABSTRACT *

THIS TECHNICAL MEMORANDUM SUMMARIZES THE PRESENT STATE-OF-THE-ART IN BOTH THE ENGINEERING AND BEHAVIORAL ASPECTS OF SIMULATION TECHNOLOGY.

THE IMPLICATIONS OF THE STATE-OF-THE-ART IN SIMULATION ARE DISCUSSED AS THEY PERTAIN TO FULFILLING THE TRAINING OBJECTIVES OF THE B-1.

IN SOME CASES IT IS BELIEVED THAT IN ORDER TO TRAIN PILOTS EFFECTIVELY IN A SIMULATOR, SOME OF THE MOTION CUES WHICH ARE PRESENT IN AN AIRCRAFT MUST BE PROVIDED. A PRACTICAL GROUND-BASED SIMULATOR, HOWEVER, HAS LIMITED MOTION CAPABILITY AND, THEREFORE, CANNOT REPRODUCE ALL THE MOTIONS EXPERIENCED IN AN AIRCRAFT. THE TASK OF THE TRAINING SYSTEM DESIGN IS TO DETERMINE WHICH CUES ARE REQUIRED FOR TRAINING AND HOW TO PROVIDE THEM. THIS SECTION ON MOTION OUTLINES THE PHYSICAL LIMITATIONS AND INTERACTIONS THAT ARE ENCOUNTERED IN TYPICAL MOTION SYSTEM DESIGNS.

JOHNSON, S.L. AND ROSCOE, S.N. WHAT MOVES THE AIRPLANE OR THE WORLD (HUMAN FACTORS), 14(2), 1972, 107-129.

* ABSTRACT *

THE LITERATURE PERTAINING TO MOTION-RELATIONSHIP VARIABLES IN

THE DISPLAY OF AIRPLANE FLIGHT ATTITUDE AND STEERING COMMANDS AND THEIR EFFECTS UPON PILOT PERFORMANCE IS REVIEWED. FACTORS CONSIDERED INCLUDE: (1) FIGURE AND GROUND RELATIONSHIPS, (2) CONTROL-DISPLAY RELATIONSHIPS, (3) WHETHER THE AIRPLANE OR THE HORIZON IS THE MOVING ELEMENT OF THE DISPLAY, AND (4) WHETHER THE PRESENTATION OF STEERING COMMANDS RESULTS IN PURSUIT OR COMPENSATORY TRACKING. THE FREQUENCY-SEPARATION PRINCIPLE IS AN UNEXPLORED APPROACH TO THE SOLUTION OF DISPLAY MOTION RELATIONSHIP PROBLEMS. A CONCLUDING SET OF REQUIREMENTS FOR FUTURE RESEARCH IS BASED ON PROBLEMS ENCOUNTERED IN PREVIOUS INVESTIGATIONS OF DISPLAY MOTION RELATIONSHIPS.

JOHNSON, S. L., WILLIGES, R. C., AND ROSCOE, S. N.
A NEW APPROACH TO MOTION RELATIONS FOR FLIGHT DIRECTOR
DISPLAYS. SAVVY, ILLINOIS, UNIVERSITY OF ILLINOIS,
INSTITUTE OF AVIATION RESEARCH LABORATORY,
TECHNICAL REPORT APL-71-20/BNR 71-2/AFBSR-71-6, OCTOBER 1971.

* ABSTRACT *

TWO NEW APPROACHES TO THE PROBLEM OF PREFERRED MOTION RELATIONSHIPS FOR ATTITUDE DISPLAYS WERE EXPLORED: A TIME-LAGGED FREQUENCY-SEPARATED KINALOG DISPLAY AND A HYBRID FREQUENCY-SEPARATED PRESENTATION EMPLOYING AILERON POSITION TO QUICKEN THE INDICATION OF BANK ATTITUDE CHANGES. EIGHT FLIGHT DIRECTOR DISPLAY CONFIGURATIONS THAT ENCOMPASSED THE COMBINATIONS OF FOUR ATTITUDE PRESENTATIONS (MOVING HORIZON, MOVING AIRPLANE, KINALOG, AND FREQUENCY-SEPARATED) AND TWO MODES OF COMMAND PRESENTATION (PURSUIT AND COMPENSATORY) WERE COMPARED IN A LINK CAT-2 FLIGHT TRAINER. OVERALL, THE MOVING AIRPLANE PRESENTATION WAS SUPERIOR TO THE MOVING HORIZON, AND THE PURSUIT CONFIGURATIONS WERE SUPERIOR TO THE COMPENSATORY CONFIGURATIONS. FURTHERMORE, COMMAND PRESENTATION INTERACTED WITH ATTITUDE PRESENTATION, THE PURSUIT MOVING AIRPLANE COMBINATION BEING DISPROPORTIONATELY SUPERIOR TO ALL OTHERS. RESULTS ARE DISCUSSED WITH REFERENCE TO PREVIOUS AND FUTURE RESEARCH.

JOHNSON, W.H. AND HSUEN, J. BRAIN BLOOD-FLOW CHANGES DURING MOTION SICKNESS. FIFTH SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE EXPLORATION, HELD AT THE NAVAL AEROSPACE MEDICAL RESEARCH LAB., PENSACOLA, FL., AUG 19-21, 1970. PUBLISHED AS NASA SP-314, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., DC., 1973.

* ABSTRACT *

SPECULATION AS TO THE POSSIBILITY OF DIMINISHED BLOOD FLOW IN THE BRAIN AS ONE OF THE FACTORS RESULTING FROM AN INCREASE IN SKELETAL MUSCLE BLOOD VOLUME CONCOMITANT WITH OTHER CHARACTER.

ISTICS OF MOTION SICKNESS LED TO THE PRESENT INVESTIGATION. THERMISTORS WERE IMPLANTED IN THE THALAMUS OF DOGS AND BLOOD FLOW CHANGES RECORDED WHILE THEY WERE SUBJECTED TO SINUSOIDAL MOVEMENT ON A TWO-POLE SWING. RESULTS OF THESE INITIAL STEPS IN A PROPOSED LONG-TERM PROJECT OF EXPLORING DIFFERENT AREAS OF THE BRAIN ARE PRESENTED.

JOHNSON, W.J. CAPT. DESIRABLE IMPROVEMENTS IN FUTURE AIRLINE FLIGHT SIMULATORS. IN PROCEEDINGS OF THE TWO-DAY SYMPOSIUM ON FLIGHT TRAINING SIMULATORS FOR THE 70'S, 14/15 OCTOBER 1970, THE ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 0BQ. PP. A-1 TO A-5

* ABSTRACT *

THIS PAPER CONTAINS THE FOLLOWING STATEMENT ON MOTION:

ONE OF THE MAIN PROBLEMS IN FLIGHT SIMULATION AND MOTION IS TO KNOW WHAT IS ACTUALLY NECESSARY TO MEET THE TRAINING REQUIREMENTS FOR DIFFERENT PHASES OF PILOT TRAINING. I QUESTION THE WISDOM OF THE APPARENT PRESENT DAY RUSH TO BUY SIX AXES MOTION EQUIPMENT. I SUSPECT IF A TEN AXES MOTION WAS DESIGNED SOMEBODY WOULD BUY IT AND IMAGINE THEY WERE ONE JUMP AHEAD OF THE FIELD.

I SERIOUSLY SUGGEST THAT A GREAT DEAL OF RESEARCH IS REQUIRED TO ESTABLISH THE PRECISE NATURE OF THE REQUIREMENT FOR MOTION TO ENABLE OPERATORS TO WRITE MORE REALISTIC SPECIFICATIONS OF MOVEMENT IN NEW SIMULATORS. WE DO REQUIRE REALISTIC SIMULATION OF THE ASYMMETRIC SWING ON LANDING AND TAKE OFF, ALSO PITCH CHANGES DURING TAKE OFF, OVERSHOOT AND APPROACH TO STALL AND IN AIR TURBULENCE. FURTHER REQUIREMENT FOR SIMULATION OF MOVEMENT OUTSIDE NORMAL MANEUVERS IS FOR THE SIMULATION OF SPATIAL DISORIENTATION WITH THE NEED TO TRAIN PILOTS TO RECOGNIZE THIS CONDITION AND TAKE CORRECTIVE ACTION. IT IS APPRECIATED THAT WORK IN THIS FIELD HAS BEEN GOING ON DURING THE LAST TWO OR THREE YEARS IN THE UNITED STATES AIR FORCE AND ALTHOUGH THE AIRLINE PROBLEM MAY NOT BE AS SEVERE AS IN THE AIR FORCES IT IS FELT THAT WE HAVE A TRAINING PROBLEM WHICH SHOULD BE DEALT WITH BY THE USE OF A SPECIAL PART TASK SIMULATOR.

JOLLEY, G.B. AND CARB. F.W. JR. : A DETERMINATION OF SELECTED COSTS OF FLIGHT AND SYNTHETIC FLIGHT TRAINING. ALEXANDRIA, VA. HUMAN RESOURCES RESEARCH ORGANIZATION, TECHNICAL REPORT 70-6, 1970.

* ABSTRACT *

AS PART OF AN ANALYSIS OF THE VALUE OF SYNTHETIC TRAINING AT

NAVTRAEQUIPCEN IH-298

THE U. S. ARMY AVIATION SCHOOL, COSTS ASSOCIATED WITH THE CONDUCT OF FLIGHT AND SYNTHETIC TRAINING IN THE INSTRUMENT PHASE OF THE ARMY'S OFFICER/WARRANT OFFICER ROTARY WING AVIATOR COURSE WERE IDENTIFIED AND COMPUTED SEPARATELY FOR EACH TYPE OF TRAINING. IT WAS FOUND THAT, FOR THE FACTORS CONSIDERED, THE HOURLY COST OF FLIGHT TRAINING AT THE TIME OF THIS STUDY (SEPTEMBER 1966) WAS APPROXIMATELY SIX TIMES AS GREAT AS THE CORRESPONDING COST OF SYNTHETIC FLIGHT TRAINING. THE REPORT DESCRIBES THE SOURCES FOR AND THE TREATMENT OF DATA, AND THE MAJOR ASSUMPTIONS MADE IN ALLOCATING THE COSTS. AN ILLUSTRATION IS PROVIDED OF THE USEFULNESS OF SUCH COST INFORMATION IN DETERMINING A COST-EFFECTIVE COMBINATION OF FLIGHT AND SYNTHETIC FLIGHT TRAINING FOR ATTAINING A PARTICULAR TRAINING GOAL. OTHER APPLICATIONS OF THE REPORTED INFORMATION ARE DISCUSSED.

JONES, J.G. AND TOMLINSON, B.N. THE REPRESENTATION OF LOW ALTITUDE ATMOSPHERIC TURBULENCE IN PILOTED GROUND-BASED SIMULATORS. 'ROYAL AIRCRAFT ESTABLISHMENT' (ENGLAND) RAE TR 71198, SEPTEMBER 1971.

* ABSTRACT *

SEVERAL ASPECTS OF THE SIMULATION OF FLIGHT IN TURBULENCE ARE REVIEWED, INCLUDING MATHEMATICAL MODELS OF AIRCRAFT RESPONSE TO TURBULENCE, MODELS AND MEASURED PROPERTIES OF ATMOSPHERIC TURBULENCE, AND THE SUBJECTIVE REACTIONS OF THE HUMAN PILOT. PILOTS APPEAR TO BE PARTICULARLY SENSITIVE TO THE LARGE, INTERMITTENT, PEAKS THAT OCCUR IN THE AIRCRAFT RESPONSE TO TURBULENCE. CONVENTIONAL GUST GENERATORS, WHICH HAVE GAUSSIAN STATISTICAL PROPERTIES, DO NOT ADEQUATELY REPRESENT THE INTERMITTENT STRUCTURE OF ATMOSPHERIC TURBULENCE. A PROPOSED DESIGN FOR AN IMPROVED GUST GENERATOR, INCORPORATING NON-LINEAR TRANSFORMATION OF A GAUSSIAN PROCESS IS OUTLINED.

JUNKER, A.M. AND LEVISON, W.H. APPLICATION OF CONTROL THEORY TO THE INVESTIGATION OF ROLL MOTION EFFECTS ON PILOT CONTROL BEHAVIOR. IEEE PROCEEDINGS OF CONTROL DECISION CONFERENCE, 1977.

* ABSTRACT *

THE APPLICATION OF MANUAL CONTROL THEORY TO THE INVESTIGATION OF THE EFFECTS OF MOTION CUES ON PILOT CONTROL BEHAVIOR IS PRESENTED. EXPERIMENTS AND MODELING APPROACHES WHICH HAVE LED TO THE DEVELOPMENT OF A PREDICTIVE MOTION SENSITIVE OPTIMAL-CONTROL PILOT-VEHICLE MODEL FOR ROLL AXIS MOTION CUES ARE DESCRIBED.

JUNKER, A.M. AND W.H. LEVISON. RECENT ADVANCES IN MODELLING THE EFFECTS OF ROLL MOTION IN THE HUMAN OPERATOR. AVIAT. SPACE ENVIRON. MED. 49(1): 328-334, 1978.

* ABSTRACT *

AN EXPERIMENT IS PRESENTED IN WHICH THE EFFECTS OF ROLL MOTIONS ON HUMAN OPERATOR PERFORMANCE WERE INVESTIGATED. THE MOTION CUES CONSIDERED WERE THE RESULT OF COMMANDED VEHICLE MOTION AND VEHICLE DISTURBANCES. AN OPTIMAL CONTROL PILOT-VEHICLE MODEL WAS USED IN THE DESIGN OF THE EXPERIMENT AND TO PREDICT SYSTEM PERFORMANCE PRIOR TO EXECUTING THE EXPERIMENT. THE MODEL PREDICTIONS AND EXPERIMENTAL RESULTS ARE COMPARED. OF THE MODEL PREDICTIONS, 78 PER-CENT ARE WITHIN 1 S.D. OF THE MEANS OF THE EXPERIMENTAL RESULTS. THE HIGH CORRELATION BETWEEN MODEL PREDICTIONS AND SYSTEM PERFORMANCE INDICATE THE USEFULNESS OF THE PREDICTIVE MODEL FOR EXPERIMENTAL DESIGN AND FOR PREDICTION OF PILOT PERFORMANCE INFLUENCED BY MOTION CUES.

JUNKER, A.M. AND PRICE, J. COMPARISON BETWEEN A PERIPHERAL DISPLAY AND MOTION INFORMATION ON HUMAN TRACKING ABOUT THE ROLL AXIS. AIAA VISUAL AND MOTION SIMULATION CONFERENCE, PROCEEDINGS, DAYTON, OHIO. APRIL 26-28, 1976, PP. 63-72.

* ABSTRACT *

A COMPARATIVE STUDY OF THE EFFECTS OF PERIPHERAL DISPLAY INFORMATION AND MOTION CUE INFORMATION ON ROLL AXIS TRACKING WAS PERFORMED. IT HAS BEEN SHOWN THAT SIMILAR MOTION INFORMATION IMPROVES TRACKING PERFORMANCE FOR SOME ROLL AXIS TRACKING TASKS. FOR THE MOTION CASE THE CUES AVAILABLE CONSISTED OF ANGULAR ACCELERATION OR VELOCITY AND LINEAR ACCELERATION. THE PERIPHERAL DISPLAY WAS DRIVEN BY PLANT ROLL RATE GIVING THE HUMAN OPERATOR ANGULAR VELOCITY INFORMATION ONLY. THE SAME INPUT FORCING FUNCTION AND PLANT DYNAMICS WERE USED FOR THE MOTION CASE AND THE PERIPHERAL DISPLAY CASE SO THAT COMPARISONS COULD BE MADE. THE TRACKING RESULTS INDICATE AN EQUIVALENT IMPROVEMENT IN PERFORMANCE FOR BOTH CASES SUGGESTING THAT ANGULAR VELOCITY INFORMATION WAS THE PRINCIPAL MOTION COMPONENT USED BY THE HUMAN CONTROLLER. THE RESULTS ALSO SUGGEST THAT PERIPHERAL DISPLAYS CAN BE USED TO ENHANCE TRACKING IN MUCH THE SAME WAY AS MOTION CUES FOR TRACKING PERFORMANCE.

JUNKER, A.M., AND REPLIGLE, C.R., MOTION EFFECTS ON THE HUMAN OPERATOR IN A ROLL AXIS TRACKING TASK, AVIATION, SPACE, AND ENVIRONMENTAL MEDICINE, 46(6): 819-822, JUNE 1975

* ABSTRACT *

TO BETTER UNDERSTAND THE EFFECTS OF MOTION ON TRACKING PERFORMANCE, A SIMULATOR CAPABLE OF BEING CONTROLLED IN A STATIC AS WELL AS MOTION MODE, WAS DEVELOPED. USING THIS SIMULATOR, 12 VOLUNTEERS, SEPARATED INTO GROUPS OF FOUR, ATTEMPTED TO TRACK A WING ANGLE TARGET DISPLAY. THE TARGET WAS DRIVEN WITH BANDLIMITED (0.5 RAD/S) GAUSSIAN NOISE SO THAT A ROLL ANGLE OF 120 DEGREES WAS EQUIVALENT TO 1 S. D. DIFFERENT CONTROL DYNAMICS (PLANTS) WERE USED FOR EACH GROUP OF VOLUNTEERS. FOR MANUAL CONTROL OF PLANTS OF THE FORM $K/(S*S)$, THE EXPERIMENTAL RESULTS INDICATE THAT LARGE AMPLITUDE ROLL MOTION IMPROVEMENT IN TRACKING PERFORMANCE. FOR CONTROL OF SIMPLER PLANTS, OF THE FORM K/S , NO IMPROVEMENT DUE TO THE PRESENCE OF THE MOTION ENVIRONMENT WAS OBSERVED.

KAIL, KARL - MOTION SIMULATOR ACTUATOR JOINT
PATENT NO. 3,577,659
FILED AUG. 6, 1969 GRANTED MAY 4, 1971

NO ABSTRACT

KAIL, KARL A. - CONSTANT SPEED PROPELLER SIMULATING MEANS FOR AVIATION TRAINERS PATENT NO. 2,439,168
FILED JULY 31, 1943 GRANTED APRIL 6, 1948

NO ABSTRACT

L. KAPLAN - COCKPIT MOTION SYSTEM FOR AIRCRAFT SIMULATORS
PATENT NO. 3,304,628
FILED MAY 21, 1965 GRANTED FEB. 21, 1967

NO ABSTRACT

KELLEY, C.M. ADAPTIVE SIMULATION: DESIGN APPLICATIONS OF SELF-ADJUSTING SIMULATORS. ENGINEERING PSYCHOLOGY BRANCH, PSYCHOLOGICAL SCIENCES DIVISION, OFFICE OF NAVAL RESEARCH. CONTRACT N00014-66-0011 NR 196-050, AUGUST 1966.

* ABSTRACT *

ADAPTIVE OR SELF-ADJUSTING SIMULATORS VARY THEIR OWN DIFFICULTY LEVEL AUTOMATICALLY AS A CONSEQUENCE OF OPERATOR

PERFORMANCE. THIS STUDY REVIEWS THEIR USEFULNESS FOR DESIGN IN TWO TECHNICAL PAPERS, AND REPRINTS THE BASIC EARLIER TECHNICAL PAPER IN THE FIELD, WHICH HAD BECOME UNAVAILABLE. THE FIRST PAPER, 'DESIGN APPLICATIONS OF ADAPTIVE SIMULATORS', REVIEWS THE HISTORY OF ADAPTIVE SIMULATION, ANALYZES AND DEVELOPS RECOMMENDED EQUATIONS AND PROCEDURES FOR ADAPTIVE APPLICATIONS, AND PRESENTS EXAMPLE DATA WITH RESPECT TO: 1) DISPLAY GAIN: 2) CONTINUOUS VS. ON-OFF CONTROL, AND 3) ONE VS. TWO VS. THREE-AXIS TASKS. THE DATA WERE GATHERED BY AN ADAPTIVE TRACKING SIMULATOR WHICH VARIED THE AMPLITUDE OF THE FORCING FUNCTION OF AN ACCELERATION TRACKING TASK AS A FUNCTION OF OPERATOR PERFORMANCE. THE SECOND PAPER, 'CROSS-ADAPTIVE OPERATOR LOADING TASKS', DESCRIBES AND ILLUSTRATES ADAPTIVE TECHNIQUES BY MEANS OF WHICH PERFORMANCE ON ONE (PRIMARY) TASK MODIFIES A SECOND (OPERATOR LOADING) TASK IN SUCH A WAY THAT PRIMARY TASK PERFORMANCE IS STANDARDIZED, AND ALL OF THE VARIANCE TRANSFERRED TO THE LOADING TASK SCORE. EXPERIMENTAL DATA ARE GIVEN COMPARING PERFORMANCE WITH A PRIMARY TASK ALONE, A PRIMARY PLUS INDEPENDENT LOADING TASK, AND A PRIMARY PLUS CROSS-ADAPTIVE LOADING TASK. RULES FOR APPLYING CROSS-ADAPTIVE LOADING TASKS ARE GIVEN.

KELLEY, C.R., BOWEN, H.M., DE GROOT, S., FRANK, P., AND CHANNEL, R.C. 'RELATIVE MOTION. II: THE NATURE OF MOTION SITUATIONS'. NAVTRADEVEN 316-1, 19 NOVEMBER 1959.

* ABSTRACT *

DESIGNERS OF OPERATIONAL AND TRAINING EQUIPMENT AND PROCEDURES IN MANY AREAS OF PILOTAGE AND NAVIGATION MUST HAVE A CLEAR UNDERSTANDING OF HOW MAN BEHAVES IN RELATIVE MOTION SITUATIONS. TO THIS END, THE PSYCHO-PERCEPTUAL AND THE MATHEMATICAL ASPECTS OF RELATIVE MOTION SITUATIONS WERE DELINEATED AND SYSTEMATIZED, AND ONE RELATIVE MOTION EXPERIMENT WAS PERFORMED IN THE LABORATORY.

THE STUDY DEFINED RELATIVE MOTION AS THE CHANGE IN THE RELATIVE POSITION OF TWO MOVING OBJECTS WHICH CAN BE PERCEIVED OR UNDERSTOOD IN TERMS OF MORE THAN ONE FRAME OF REFERENCE. A BACKGROUND FOR PSYCHOLOGICAL THEORY WAS DEVELOPED WHICH YIELDED GUIDELINES FOR SELECTING THE 'OUTSIDE-IN' VERSUS THE 'INSIDE-OUT' REFERENCE FRAME FOR OPERATOR TASKS. THE APPROPRIATENESS OF A REFERENCE FRAME WAS FOUND TO BE A FUNCTION OF:

- A. THE SPEED WITH WHICH A GIVEN TASK MUST BE CARRIED OUT AND OTHER OPERATOR REQUIREMENTS.
- B. THE PHYSICAL ENVIRONMENT, ESPECIALLY AS IT AFFECTS THE RICHNESS AND SIZE OF VISUAL CUES.
- C. THE NATURE OF ACCESSORY CUES (E.G. INSTRUMENTATION).

THE EXPERIMENTAL PORTION OF THE STUDY IDENTIFIED SHAPE OF A TARGET AS ONE OF THE CRUCIAL CLUES TO ITS MOVEMENT WHEN OBSERVED BY A MOVING OBSERVER. IT ALSO IDENTIFIED AN IMPORTANT CONSTANT ERROR IN THE JUDGMENT OF A MOVING TARGET BY A MOVING OBSERVER.

KELLEY, CHARLES R., DE GROOT, SYBIL, AND BOWEN, HUGH M.
RELATIVE MOTION III: SOME RELATIVE MOTION PROBLEMS IN AVIATION
NAVTRAEGUICEN 316-2, CONTRACT N61339-316, DUNLAP AND ASSOCIATES,
INC. JAN. 1961, 67 PP. AD 256346

* ABSTRACT *

TO EXPLORE RELATIVE MOTION PROBLEMS IN A VARIETY OF PILOT AND NAVIGATOR TASKS, BOTH FIELD AND LABORATORY STUDIES WERE CONDUCTED. IN THE FORMER, METHODS USED BY PILOTS TO FLY INTERCEPTS WERE SURVEYED; THE GUIDANCE OF AIR-TO-GROUND MISSILES WAS ANALYZED; AND RELATIVE MOTION PROBLEMS IN ATTITUDE AND NAVIGATION DISPLAYS (INCLUDING THE ANIP DISPLAY) WERE IDENTIFIED. TWO EXPERIMENTS WERE CARRIED OUT TO DETERMINE NATURAL RESPONSES TO 'INSIDE-OUT' DISPLAYS AS A FUNCTION OF DISPLAY SIZE AND TO DETERMINE HOW TO ELIMINATE WRONG RESPONSES TO ROLL INFORMATION PRESENTED ON SUCH DISPLAYS (REVERSAL ERRORS). THE STUDY CONFIRMED THE SUPERIORITY OF 'OUTSIDE-IN' DISPLAYS, MADE SPECIFIC RECOMMENDATIONS FOR THE DESIGN OF NAVIGATION AND ATTITUDE DISPLAYS FOR AIR AND SPACECRAFT, AND SUGGESTED WAYS OF ELIMINATING REVERSAL ERRORS. IT ALSO RECOMMENDED PROCEDURES FOR MISSILE GUIDANCE, AND PROVIDED INSIGHTS INTO THE CLUES USED BY PILOTS IN VISUAL INTERCEPTS.

KELLY, LLOYD, L.
THE PILOT MAKER. NEW YORK: GROSSET AND DUNLAP, 1970.

* ABSTRACT *

THIS BOOK DESCRIBES THE DEVELOPMENT OF THE ORIGINAL LINK TRAINER TO THE MODERN AIRCRAFT AND SPACECRAFT SIMULATORS. THE ORIGINAL LINK PILOT-MAKER WAS A RELATIVELY SIMPLE DEVICE COMPARED TO MODERN SIMULATORS. HOWEVER, IT WAS A MOVING BASE TRAINER AND COULD SIMULATE ROLL, PITCH AND YAW. THE QUESTION OF THE NEED OF MOTION IN SIMULATORS WAS DISCUSSED. LINK HAD ORIGINALLY USED MOTION IN THE EARLY TRAINERS. LATER, THE COMPANY MOVED FROM THAT CONCEPT BECAUSE THE MOTION IN THE TRAINER THAT WAS BEING PROVIDED WAS INCOMPATIBLE WITH THE FEEL OF A REAL AIRCRAFT. LINK'S FIRST COMPLETELY ELECTRONIC MODEL WAS A FIXED-BASE TRAINER. LATER STILL, LINK DECIDED IN FAVOR OF INCLUDING MOTION AGAIN IN THEIR TRAINERS. SINCE THE 1940'S WHEN THE QUESTION OF THE NEED OF MOTION WAS FIRST VIGOROUSLY DEBATED AT LINK, THERE HAVE BEEN SEVERAL REVERSALS, FIRST

FAVORABLE, THEN UNFAVORABLE TOWARDS THE INCLUSION OF MOTION CUES IN SIMULATORS. IN A SENSE, THIS HISTORICAL SKETCH REFLECTS OUR PRESENT DAY THINKING ON THE SUBJECT OF MOTION SIMULATION. DESPITE THE COMMENT ON PAGE 121 OF THE BOOK, THAT THE RESULTS OF MILITARY TESTS WERE UNEQUIVOCALLY IN FAVOR OF SUITABLE MOTION SYSTEMS IN SIMULATORS, THE QUESTION APPEARS TO KEEP RECYCLING WITHOUT ANY DEFINITIVE ANSWER.

KEMMERLING, P.T., JR., DYNAMIC CHARACTERISTICS OF FLIGHT SIMULATOR MOTION SYSTEMS. PREPARED FOR AGARD SPECIALISTS MEETING ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS, BELGIUM, 24-27 APRIL 1978.

* ABSTRACT *

IN THE COURSE OF THE WORK ACCOMPLISHED BY WORKING GROUP #07, MANY DIFFERENT APPROACHES TO THE GOAL OF ESTABLISHING A SET OF MEANINGFUL CHARACTERISTICS OF MOTION SYSTEMS HAVE BEEN CONSIDERED. AS INDIVIDUAL MEMBERS CONTINUE TO TEST THESE MEASUREMENT TECHNIQUES IT SEEMS LIKELY THAT SOME OF THEM MAY BE AMELIORATED OR DISCARDED, AND/OR NEW ONES ADDED. FOR EXAMPLE, DURING RECENT MEASUREMENTS ON BACKLASH TAKEN ON THE NLR FOUR-DEGREE-OF-FREEDOM MOTION SYSTEM, RESEARCHERS COULD NOT DETECT BACKLASH IN THE ACCELERATION SIGNAL, USING THE WORKING GROUP'S PROCEDURES. IT SEEMS CERTAIN THAT SOME IMPROVEMENTS IN THESE MEASUREMENT TECHNIQUES FOR BACKLASH WILL HAVE TO BE MADE.

IN ADDITION TO MEASURING THE MOTION SYSTEM TRANSFER FUNCTION WITH SINUSOIDAL EXCITATION, IT MAY BE CONVENIENT TO ACCURATELY MEASURE CERTAIN PARAMETERS BY MEANS OF A STATIC TRANSFER CHARACTERISTIC. THIS IS SIMPLY A RECTANGULAR PLOT OF THE SYSTEM TRANSFER FUNCTION UNDER QUASI-STATIC CONDITIONS, ELIMINATING ANY EFFECTS OF DYNAMICS. IT DEFINES THE ACCURACY AND LINEARITY OF REPRODUCTION OF THE COMMAND TO THE SYSTEM AT ZERO AND VERY LOW RATES, AND AT LARGE EXCURSIONS OF THESE VARIANTS.

ANOTHER USEFUL MEASUREMENT TECHNIQUE IS THE TRANSIENT RESPONSE. DEFINED AS THE TIME HISTORY OF THE RESPONSE OF THE MOTION SYSTEM TO A STEP INPUT COMMAND, IT IDENTIFIES THE INITIAL DELAY, THE DEGREE OF DAMPING, AND THE SETTLING TIME.

THESE MEASUREMENT TECHNIQUES ARE NOW BEING REFINED AS THE WORKING GROUP'S MEMBERS PERFORM THEIR INDEPENDENT STUDIES, AND THEIR FINAL PRODUCT WILL BE A VALUABLE TAXONOMY OF THOSE PHYSICAL CHARACTERISTICS OF FLIGHT SIMULATOR MOTION GENERATION SYSTEMS THAT ARE IMPORTANT AND SIGNIFICANT IN PROVIDING HIGH FIDELITY REALISTIC MOTION CUES TO THE PILOT.

THIS IS OF SPECIFIC IMPORTANCE TO THE NEWLY FORMED ASMP - FMP - GCP MULTIPART WORKING GROUP ON FIDELITY OF FLIGHT SIMULATION FOR PILOT TRAINING - WORKING GROUP 10. AS PART OF ITS SCOPE OF EFFORT, WORKING GROUP 10 WILL LOOK AT MOTION SIMULATION HARD-

WARE, ITS QUALITY OF PRODUCED MOTIONS AND THE GENERATION OF MOTION CUES, AND THE MOTION CHARACTERISTICS DEFINED BY WORKING GROUP 07 SHOULD FORM AN EXCELLENT BASELINE FOR DETERMINING THE OPTIMAL USE OF THE CURRENTLY AVAILABLE MOTION SYSTEMS.

KENNEDY, R.S. MOTION SICKNESS QUESTIONNAIRE AND FIELD INDEPENDENCE SCORES AS PREDICTORS OF SUCCESS IN NAVAL AVIATION TRAINING. 'AVIATION, SPACE, AND ENVIRONMENTAL MEDICINE', NOV. 1975, 1349-1352.

* ABSTRACT *

THE PRESENT REPORT HAS SHOWN THAT A MOTION SICKNESS QUESTIONNAIRE CAN BE USED TO PREDICT SUSCEPTIBILITY TO MOTION SICKNESS OR FLIGHT TRAINING SUCCESS, DEPENDING ON THE ITEMS SCORED. THERE IS A DISCUSSION OF THE THEORY THAT MOTION SICKNESS RESULTS FROM CONFLICTING PERCEPTUAL INPUTS, THIS THEORY IS RELATED TO AIRCRAFT OPERATING CONDITIONS. SCORES ON A PERSONALITY TEST WHICH APPEAR TO BE RELATED TO SIMILAR PERCEPTUAL PHENOMENA ARE RELATED TO AVIATION SUCCESS. ONE PHENOTYPE, FIELD INDEPENDENCE, SEEMS TO BE PROMISING IN THIS REGARD. IN ADDITION TO USE OF THIS FINDING IN AVIATOR SELECTION, IT IS FELT THAT STUDIES OF THIS TRAIT, AS IT RELATES TO AN ABILITY TO RECONCILE CONFLICT AND TO MOTION SICKNESS INSUSCEPTIBILITY, SHOULD BE CONDUCTED.

KENNEDY, R. S., MORONEY, W. F., BALE, R. M., GREGGIRE, H. G., AND SMITH, D. G.
MOTION SICKNESS SYMPTOMATOLOGY AND PERFORMANCE DECREMENTS OCCASIONED BY HURRICANE PENETRATIONS IN C-121, C-130, AND P-3 NAVY AIRCRAFT.
'AEROSPACE MED.' 43(11): 1235-1239. 1972.

* ABSTRACT *

THE PURPOSE OF THIS RESEARCH WAS TO DETERMINE THE COMPARATIVE INCIDENCE OF MOTION SICKNESS AND THE AMOUNT OF PERFORMANCE DECREMENT ASSOCIATED WITH HURRICANE PENETRATIONS BY THREE TYPES OF NAVY AIRCRAFT (P-3, C-130, AND C-121). THREE DIFFERENT NAVY AIRCRAFT MADE SIX FLIGHTS, EACH FLIGHT PENETRATING HURRICANE INGA SEVERAL TIMES. THE CONTROLLING AIRCRAFT WAS A C-121 WHICH IS ROUTINELY EMPLOYED BY THE NAVY FOR HURRICANE PENETRATIONS. THE OTHER TWO AIRCRAFT (C-130 AND P-3) FOLLOWED THE C-121 INTO THE STORM AT SHORT INTERVALS AND PENETRATED THE STORM AT THE SAME ALTITUDE, HEADING, AIRSPEED, ETC.

MOST SUBJECTS EXPERIENCED SLIGHT TO MODERATE MALAISE DURING THE FLIGHTS, WITH GENERALLY HIGHER SICKNESS RATES OCCURRING DURING THE MORE TURBULENT FLIGHTS. THE SUBJECTS' OVERALL FLYING EXPERIENCES AFFORDED SOME PROTECTION FROM SICKNESS; AIRSICKNESS

RATES IN THE C-121 WERE GREATER THAN THOSE IN THE C-130 AND P-3. THE RESULTS ON A COMPLEX COUNTING TASK SHOWED THAT PERFORMANCE DECREASED AS A FUNCTION OF INCREASED TURBULENCE.

IN-FLIGHT RECORDINGS OF LINEAR AND ANGULAR ACCELERATIONS WERE RELATED TO SICKNESS RATES, AND IT IS SUGGESTED THAT THE FREQUENCY OF THE LINEAR OSCILLATIONS MAY BE A MORE IMPORTANT VARIABLE FOR PRODUCING MOTION SICKNESS THAN THE MAGNITUDE OF THE ACCELERATION PER SE. FURTHER, BECAUSE THE RELATIONSHIP BETWEEN MOTION SICKNESS AND LINEAR ACCELERATIONS DOES NOT APPEAR TO BE LINEAR, THIS FINDING COULD HAVE IMPORTANT IMPLICATIONS FOR THE DESIGN OF OTHER FORCE ENVIRONMENTS. THESE IMPLICATIONS ARE DISCUSSED.

KENNELLY, E.O., 'DEVELOPMENT OF A MULTIPURPOSE RESEARCH SIMULATOR', GRUMMAN RESEARCH BROCHURE, GRUMMAN AIRCRAFT ENGINEERING CO., BETHPAGE, NEW YORK, FEBRUARY 1959.

* ABSTRACT *

THIS EQUIPMENT CONSISTS OF A MOTION SIMULATOR, A LARGE VARIETY OF SERVO EQUIPMENT FOR DRIVING VARIOUS INSTRUMENTS AND A VISUAL DISPLAY OF THE OUTSIDE WORLD. OUR DYNAMICISTS AND OUR HUMAN FACTORS PEOPLE SET UP REQUIREMENTS FOR NEW SIMULATION EQUIPMENT. THIS EQUIPMENT CAN BE BROKEN DOWN INTO SEVERAL BROAD FIELDS.

IN THE VTOL AND STOL AREAS, THERE ARE PROBLEMS OF CONTROL WHICH ARE NOT ONLY UNUSUAL IN OUR EXPERIENCE, BUT ALSO PARTICULARLY UNUSUAL BECAUSE NEAR-THE-GROUND FLIGHT POSES CRITICAL CONTROL PROBLEMS WHICH REQUIRE SPECIAL SIMULATION OF GROUND PROXIMITY IN THE VISUAL DISPLAY. SINCE THIS FIELD PLACES A PREMIUM ON PILOT RESPONSE, WE FELT THAT THE ANGULAR ACCELERATIONS AND VELOCITIES OF THE COCKPIT WOULD BE A PARTICULARLY USEFUL FEATURE IN THIS STUDY. A DESCRIPTION OF THE MOTION SYSTEM IS PROVIDED ALONG WITH ITS CAPABILITIES.

KEY, DAVID L., ODNEAL, BILLY L., AND SINACORI JOHN B. MISSION ENVIRONMENT SIMULATION FOR ARMY ROTORCRAFT DEVELOPMENT-REQUIREMENTS AND CAPABILITIES. AEROMECHANICS LABORATORY, U.S. ARMY AVIATION R&D COMMAND, AMES RESEARCH CENTER, MOFFETT FIELD, CA. PRESENTED AT AGARD FLIGHT MECHANICS PANEL SPECIALISTS' MEETING ON FILOTTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS, BELGIUM, APRIL 24-27, 1978.

* ABSTRACT *

THE HELICOPTER IS NATURALLY A GROUND CONTACT MACHINE PAR EXCELLENCE, AND ITS MISSION USE IN ARMY AVIATION IS MORE CHARACTERISTIC OF A FLYING WEEF OR TANK THAN OF AN AIRPLANE. THIS PUTS THE

ARMY AVIATOR IN AN ENVIRONMENT RICH IN DETAIL BOTH FROM THE GROUND AND FROM THE ATMOSPHERE. TERRAIN FEATURES, BOTH NATURAL AND MAN-MADE, VISIBILITY FACTORS OF WEATHER AND DARKNESS, AND ATMOSPHERIC CHARACTERISTICS OF WIND, TURBULENCE, AND GROUND EFFECT ALL HAVE TO BE REPRESENTED TO THE HELICOPTER PILOT IN SIGNIFICANT DETAIL TO PROVIDE A MEANINGFUL SIMULATION.

THE AEROMECHANICS LABORATORY OF THE U.S. ARMY AVIATION R&D COMMAND (AVRADCOM) IS ENGAGED IN DEVELOPING A SIMULATION CAPABILITY TO SUPPORT AVIATION SYSTEM DEVELOPMENT AND SYSTEM INTEGRATION. THIS EFFORT IS BEING PERFORMED JOINTLY WITH NASA AT THE AMES RESEARCH CENTER. EXISTING FACILITIES AT THE AMES RESEARCH CENTER HAVE BEEN USED TO DEVELOP MOTION SYSTEM REQUIREMENTS. ALTHOUGH THESE ARE PARTICULARLY SEVERE DUE TO THE HIGH MANEUVERABILITY REQUIRED IN THE TERRAIN FLYING ENVIRONMENT, THEY CAN BE ADEQUATELY ACHIEVED BY UPGRADING THE NASA VERTICAL MOTION SYSTEM PRESENTLY UNDER DEVELOPMENT. ADEQUATE SIMULATION OF THE VISUAL ENVIRONMENT WILL BE MUCH MORE DIFFICULT TO ACHIEVE. THE RICH AND VARIED DETAIL VISIBLE IN TERRAIN FLIGHT MUST BE PRESENTED BY A WIDE FIELD-OF-VIEW SYSTEM WITH MUCH DETAIL AND HIGH RESOLUTION. THE ROTARY-WING R&D SIMULATOR MUST HAVE GREAT VERSATILITY FOR EASY CHANGE OF CAB CONFIGURATIONS AND THE CAPABILITY TO ACCOMMODATE A TWO OR THREE MAN CREW. BASIC SPECIFICATIONS FOR AN ADEQUATE VISUAL DISPLAY HAVE BEEN DEVELOPED AND ARE COMPARED IN THIS REPORT WITH CURRENT AND FORECASTED TECHNIQUES FOR IMAGE GENERATION AND PRESENTATION. RESULTS OF A STUDY PERFORMED TO DETERMINE THE FEASIBILITY OF MEETING THESE REQUIREMENTS USING THE CURRENT TECHNOLOGY OF TV CAMERA-MODEL IMAGE GENERATION AND PROJECTED DISPLAY IS DISCUSSED AND AN ASSESSMENT OF THE POSSIBILITY THAT COMPUTER GENERATED IMAGERY (CGI) CAN ACHIEVE THE DESIRED LEVEL OF DETAIL IS PRESENTED.

 KIDD, E.A., BULL, GL, AND HARPER, R.P. IN-FLIGHT SIMULATION THEORY AND APPLICATION. NORTH ATLANTIC TREATY AND ORGANIZATION, ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT REPORT 368, APRIL 1961.

* ABSTRACT *

THIS REPORT DEALS WITH THE APPLICATION OF SIMULATION TECHNIQUES TO THE PROBLEMS OF DETERMINING AIRCRAFT HANDLING QUALITIES. ANALOG COMPUTERS, FIXED-BASE SIMULATORS, AND VARIOUS OTHER GROUND MACHINES ARE DISCUSSED. IN PARTICULAR, THE VARIABLE-STABILITY TYPE ARE DEALT WITH. THE CONCLUSION IS DRAWN THAT THE SOLUTION OF THE VARIOUS PROBLEMS OF HANDLING QUALITIES REQUIREMENTS AND OF CONTROL SYSTEM DEVELOPMENT REQUIRED THE USE OF GROUND-BASED SIMULATORS AND IN-FLIGHT SIMULATORS AS COMPLEMENTARY TOOLS. (AUTHOR)

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KIDD, E.A. AND HARPER, R.P., JR. FIXED-BASE AND IN-FLIGHT SIMULATION OF LONGITUDINAL AND LATERAL-DIRECTIONAL HANDLING QUALITIES FOR PILOTED RE-ENTRY VEHICLES. CORNELL AERONAUTICAL LABORATORY REPORT NO. TE-15516-F-1, PREPARED FOR THE AIR FORCE FLIGHT DYNAMICS LABORATORY, AIR FORCE SYSTEMS COMMAND, WRIGHT PATTERSON AIR FORCE BASE, OHIO, TECH. DOCUMENTARY REPORT 'ASD-TDR-61-362'. FEB. 1964.

* ABSTRACT *

THE RESULTS OF A RESEARCH INVESTIGATION OF LONGITUDINAL AND LATERAL-DIRECTIONAL FLYING QUALITIES FOR THE RE-ENTRY MISSION ARE REPORTED. THE RESEARCH PROGRAM UTILIZED PRIMARILY A HIGH-FIDELITY FIXED-BASE GROUND SIMULATOR WITH EVALUATIONS MADE BY THREE PILOTS. ONE OF THE THREE PILOTS ALSO MADE IN-FLIGHT EVALUATIONS OF LONGITUDINAL FLYING QUALITIES IN THE SAME VEHICLE, A THREE-AXIS VARIABLE STABILITY AIRPLANE FLOWN WITH A TWO-AXIS SIDE CONTROLLER AND CONVENTIONAL RUDDER PEDALS.

THE PROGRAM RESULTS ARE REPORTED AND DISCUSSED. CONTROL SENSITIVITY EVALUATIONS WERE COMPARED TO CENTER STICK RESULTS OF EARLIER WORK. THE LONGITUDINAL FLYING QUALITIES AS EVALUATED BOTH ON THE GROUND SIMULATOR AND IN FLIGHT ARE COMPARED AND RELATED TO EARLIER INVESTIGATIONS. PILOT RATING VARIABILITY, BOTH INTERPILOT AND INTRAPILOT, ARE QUANTIZED AND DISCUSSED FOR THE GROUND AND FLIGHT EXPERIMENTS. PERFORMANCE MEASURES ARE REPORTED.

PILOT COMMENT DATA SUGGESTS THAT PROPRIOCEPTIVE CUES OF FLIGHT MAY NOT ACCOUNT FOR ALL THE DIFFERENCES BETWEEN FLIGHT AND GROUND SIMULATOR RESULTS. SOME DIFFERENCE MAY BE DUE TO THE ACUTE AWARENESS IN FLIGHT OF THE STRUCTURAL LIMITATIONS OF THE AIRCRAFT, AND THE CONSEQUENTIAL CHANGE IN CONTROL CHARACTERISTICS OF THE PILOT.

KIRK, W.C. AND STARK, E.A. REPORT OF THE VISIT TO THE TWA TRAINING CENTER KANSAS CITY, ON AUGUST 31, 1967. GENERAL PRECISION, INC. LINK GROUP-SYSTEMS DIVISION, INTER-OFFICE CORRESPONDENCE, MEMO NO. WCK/EAS 67-267, SEPTEMBER 7, 1967.

* ABSTRACT *

THE OBJECTIVES OF THE TRIP WERE TO OBTAIN TWA'S OPINIONS ON HOW ACCURATELY THE PRESENT 3 DF MOTION SYSTEM SIMULATES ACTUAL FLYING SITUATIONS. SPECIFICALLY,

1. WHAT CUES ARE MISSING IN OUR MOTION SYSTEM SIMULATION.
2. WHAT FALSE CUES ARE PRESENT
3. HOW REPRESENTATIVE ARE THE POSITIVE CUES
4. WHAT AREAS NEED IMPROVING IN THE MOTION SYSTEM.
5. WHAT IS THE POSSIBILITY OF RUNNING TESTS ON TWA SIMULATORS AND AIRCRAFT IN ORDER TO DETERMINE ACTUAL FORCES FELT BY THE PILOT.

KIRKPATRICK, M. AND BRYE, R.G. MAN-MACHINE EVALUATION OF
MOVING-BASE VEHICLE SIMULATION MOTION CUES. NASA CR-120706,
1974.

* ABSTRACT *

THE AUTHORS REPORT ON A MOTION CUE INVESTIGATION DEALING WITH
HUMAN FACTOR ASPECTS OF HIGH FIDELITY SIMULATION CARRIED OUT ON
THE GENERAL PURPOSE SIMULATOR AT NASA'S MARSHALL SPACE FLIGHT
CENTRE, HUNTSVILLE, ALABAMA. THIS SIMULATOR HAS SIX DEGREES OF
FREEDOM AND A VERY SOPHISTICATED VISUAL SYSTEM. THE AIM WAS TO
PROVIDE ADDITIONAL GENERAL DATA ON NON-VISUAL MOTION THRESHOLDS
AND TO ESTABLISH VELOCITY CHANGE RATES FOR SPECIFIC USE IN WASH-
OUT TECHNOLOGY IN THIS SIMULATOR. WASHOUT OF TRANSLATION OR
ATTITUDE RATES IN SUCH A SIMULATOR INVOLVES CONTRADICTIONARY CUES
SINCE, DURING WASHOUT, APPROPRIATE VISUAL CUES (ASSOCIATED WITH
A CONSTANT RATE) WOULD BE AVAILABLE BESIDES THE MOTION CUES.
SINCE ACCELERATION THRESHOLD STUDIES HAVE TYPICALLY BEEN CONDUCTED
UNDER VISUALLY IMPOVERISHED CONDITIONS, THE AUTHORS UNDERTOOK
TO TEST THE HYPOTHESIS THAT ACCELERATION SENSITIVITY WOULD
BE REDUCED DURING A VEHICLE CONTROL TASK INVOLVING VISUAL
FEEDBACK, AS COMPARED WITH A CONDITION WHERE THE SUBJECT IS IN
DARKNESS AND MAKING NO CONTROL RESPONSES. SUCH A DIFFERENTIAL
SENSITIVITY EFFECT WOULD PERMIT HIGHER WASHOUT VELOCITY CHANGE
RATES DURING ACTUAL VEHICLE SIMULATION. THE TESTS WERE CARRIED
OUT IN PITCH, IN HEAVE AND IN SWAY MODES. THE SIMULATOR WAS
PROGRAMMED TO PROVIDE VARYING ACCELERATION LEVELS AND THE METHOD
OF FORCED CHOICE, BASED ON THE THEORY OF SIGNAL DETECTABILITY,
WAS USED TO DETERMINE THRESHOLDS.

KLEIN, H.P.
W77-70118 (RESEARCH SUMMARY) 1977
AMES RESEARCH CENTER, MOFFETT FIELD, CALIF.
SIMULATION TECHNOLOGY FOR AERONAUTICS

* ABSTRACT *

THE OBJECTIVES OF THIS RTOP ARE TO PROVIDE A SCIENTIFIC AND
TECHNICAL BASE OF INFORMATION THAT CAN BE USED AS A RESOURCE TO
DEVELOP VALID, RELIABLE AND ECONOMICAL SIMULATORS FOR AERONAU-
TICAL RESEARCH, DEVELOPMENT AND CREW TRAINING. SPECIFIC OB-
JECTIVES ARE: TO DEVELOP ADVANCED HARDWARE AND SOFTWARE CON-
CEPTS FOR HIGH FIDELITY SIMULATION OF VISION, MOTION AND AURAL
ENVIRONMENTS; TO EVALUATE EXISTING AND PROTOTYPE SIMULATOR SYS-
TEMS USING COMPREHENSIVE PSYCHOLOGICAL AND ENGINEERING ASSES-
SMENT TECHNIQUES; AND TO DEVELOP TASK RELATED FIDELITY CRITERIA
FOR SIMULATORS BASED ON A DETAILED ANALYSIS OF HUMAN OPERATOR
REQUIREMENTS AND ENGINEERING PRINCIPLES. (1) PERCEPTION AND
HUMAN PERFORMANCE STUDIES WILL BE CONTINUED IN-HOUSE WITH AN
EMPHASIS ON DEVELOPING TASK RELATED FIDELITY CRITERIA AND

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ASSOCIATED METHODS FOR MEASURING THE FIDELITY OF SIMULATORS; (2) EXISTING SIMULATORS AND SIMULATOR SUBSYSTEMS WILL BE EVALUATED UTILIZING BOTH TRADITIONAL ASSESSMENT METHODS AND THE NEW TECHNIQUES DEVELOPED IN (1); (3) PROMISING NEW VISUAL SCENE TECHNOLOGY DEVELOPMENT WILL BE CONTINUED IN-HOUSE; AND (4) CONTRACTUAL AND IN-HOUSE STUDIES WILL BE INITIATED TO DEVELOP NEW OR IMPROVED COMPUTATIONAL METHODS AND SOFTWARE SYSTEMS FOR VISUAL SCENE GENERATION, MOTION SYSTEM LOGIC, AND THE HIGH FIDELITY SIMULATION OF AURAL CUES.

KLIER, S. AND GAGE, H.
MOTION FACTORS IN FLIGHT SIMULATION. GRUMMAN AEROSPACE CORP.
FOR THE 'NAVAL TRAINING DEVICE CENTER', NAVTRADEVEN TECHNICAL
REPORT 68-C-007-1, DECEMBER 1970

* ABSTRACT *

A STUDY WAS PERFORMED TO INVESTIGATE THE EFFECT OF DIFFERENT SIMULATOR MOTION CONDITIONS ON PILOT PERFORMANCE. IT WAS INTENDED TO EXPLORE THE CUEING FUNCTION OF SIMULATOR MOTION. SUBJECTS WERE REQUIRED TO PERFORM A SIMULATED AIR-TO-AIR GUNNERY TASK UNDER FOUR CONDITIONS OF MOTION WHERE THE FREQUENCY COMPONENTS OF SUCH MOTION INPUTS WAS LIMITED TO 0HZ (NO MOTION) 0-1.0 HZ, 0-2.5 HZ, 0-3.5 HZ RESPECTIVELY. THESE CONDITIONS WERE HYPOTHESIZED TO INTERACT DIFFERENTLY WITH CONCOMITANT VISUAL MOTION CUES. RESULTS OF PERFORMANCE ACCURACY (E.G. PERCENT TIME-ON-TARGET) INDICATED A TENDENCY FOR THE ORDER OF CONDITIONS FROM BEST TO WORST TO BE 0-2.5 HZ, 0-1.0 HZ, 0-3.5 HZ, 0 HZ. SIMULATOR MOTION PRODUCED BETTER ACCURACY PERFORMANCE THAN NO MOTION. THERE WAS A SIGNIFICANT LEARNING OR PRACTICE EFFECT AS A RESULT OF CONTINUED EXPOSURE TO THE TASK. OTHER PERFORMANCE PARAMETERS SHOWED NO SYSTEMATIC DIFFERENCES AS A FUNCTION OF EXPERIMENTAL CONDITION. THESE VARIABLES MAY HAVE BEEN AFFECTED BY NOISE IN RESPONSE OF THE MOTION PLATFORM WHICH TENDED TO MITIGATE DIFFERENCES AMONG THE EXPERIMENTAL CONDITIONS. IN GENERAL, THE RESULTS OF THIS STUDY APPEAR TO CONFIRM INDICATIONS IN PREVIOUS STUDIES THAT SIMULATOR MOTION NEED NOT BE A FAITHFUL REPRODUCTION OF REAL-LIFE MOTION IN ORDER TO PROVIDE ESSENTIAL MOTION CUES. IT IS RECOMMENDED THAT THE FINDINGS BE INCORPORATED IN THE DEVELOPMENT OF FLIGHT MOTION SIMULATORS. (AUTHOR)

KNAPP, F.A.
PROGRAMMING TECHNIQUES FOR THE AUTOMATIC MONITORING OF HUMAN PERFORMANCE. WRIGHT-PATTERSON AFB, OHIO. AEROSPACE MEDICAL RESEARCH LABORATORIES, TR AMRL-TR-66-16.
APRIL 1966.

* ABSTRACT *

THIS REPORT DESCRIBES THE ORGANIZATIONAL AND OPERATIONAL DESIGN OF A DIGITAL COMPUTER PROGRAM FOR THE AUTOMATIC MONITORING OF HUMAN PERFORMANCE DURING SIMULATED TRAINING MISSIONS. THE COMPUTER PROGRAM, NOW IN ITS DEVELOPMENTAL STAGE, IS DESIGNED TO SERVE THE DUAL AND INTER-DEPENDENT PURPOSES OF (1) ASSISTING IN THE ANALYSIS AND DETERMINATION OF MEANINGFUL PERFORMANCE MEASURES AND PERFORMANCE CRITERIA AND (2) USING THESE CRITERIA TO AUTOMATICALLY MONITOR HUMAN PERFORMANCE, INCLUDING PERFORMANCE EVALUATION (SCORING), ADAPTIVE TASK SEQUENCING, AND THE AUTOMATIC INITIATION OF SIMULATED SYSTEM MALFUNCTIONS FOR TRAINING IN EMERGENCY PROCEDURES. A DESCRIPTION IS PROVIDED OF A CRITERIA FORMAT THAT AIDS THE USER OF THE AUTOMATIC MONITORING PROGRAM IN DEFINING CRITERIA WITH VARIABLE TOLERANCES FOR CONCEIVABLY ANY AEROSPACE TASK OR MISSION. SOME PROJECTIONS ARE MADE ABOUT POSSIBLE USES OF THE RESEARCH-ORIENTED AUTOMATIC MONITORING PROGRAM TO (A) VARY CRITERIA AS THE SKILL LEVEL OF A PARTICULAR STUDENT INCREASES, (B) HOLD SELECTED FLIGHT VARIABLES CONSTANT TO ALLOW THE TEACHING OF ISOLATED SKILLS ON A PROGRESSIVE BASIS, (C) EFFECT 'OVERLEARNING' OF SELECTED SKILLS BY CONTROLLING THE OUTPUTS TO THE COCKPIT, AND (D) AID IN DEBUGGING SIMULATION PROGRAMS. A TOPICAL FLOW-CHART IS PROVIDED FOR THE ENTIRE AUTOMATIC MONITORING PROGRAM.

KSCI, U.C. - AMUSEMENT AND TARGET PRACTICING DEVICE
 PATENT APPLICATION #2,661,954
 FILED JULY 14, 1953 GRANTED DEC. 8, 1953

NO ABSTRACT

KREVERMANS, W.P. AND JANSSEN, C.O.
 DESIGN AND PERFORMANCE OF THE FOUR DEGREES OF FREEDOM MOTION SYSTEM OF THE NLR RESEARCH FLIGHT SIMULATOR. NATIONAL AEROSPACE LABORATORY, THE NETHERLANDS NLR MP 75038 1975

* ABSTRACT *

THIS PAPER DESCRIBES THE MOTION SYSTEM OF THE NLR RESEARCH FLIGHT SIMULATOR WITH FREEDOM OF MOTION IN HEAVE, ROLL, PITCH, AND YAW. TO GIVE GOOD MOTION CUES, SMOOTH OPERATION WITHOUT ANY JERKS IS REQUIRED. TO THIS END SPECIFIC HYDRAULIC JACKS HAVE BEEN DEVELOPED IN WHICH STICK-SLIP PHENOMENA ARE ELIMINATED BY INTRODUCING HYDROSTATIC BEARING BETWEEN THE MOVING PISTON AND ROD AND THE FIXED CYLINDER, RESULTING IN AN ACCELERATION THRESHOLD LEVEL BELOW 0.01 G. A MATHEMATICAL MODEL HAS BEEN PREPARED TO SIMULATE AND STUDY THE BEHAVIOR OF THE HYDRAULIC JACKS. RESULTS ARE GIVEN OF MEASUREMENTS ON SINGLE JACKS AND THE COMPLETE SYSTEM, COMPRISING ACCELERATION

NOISE AND THRESHOLD LEVEL, DYNAMIC RESPONSE AND PERFORMANCE DIAGRAMS.

BECAUSE OF THE REQUIRED OIL PRESSURE FOR THE HYDROSTATIC BEARING, SPECIAL PROCEDURES HAVE TO BE FOLLOWED TO START AND STOP THE OPERATION OF THE SYSTEM. A DESCRIPTION IS GIVEN OF THE PRINCIPLES OF THE SAFETY SYSTEM APPLIED.

KORRANCE, J.M. EFFECTS OF GROUND-BASED AIRCRAFT SIMULATOR MOTION CONDITIONS UPON PREDICTION OF PILOT PROFICIENCY. AVIATION RESEARCH LABORATORY, INSTITUTE OF AVIATION, UNIVERSITY OF ILLINOIS, SAVOY, FOR THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH, REPORT NO. ARL-74-5/AFOSR-74-3, APRIL 1974.

* ABSTRACT *

THREE GROUPS OF THIRTY PILOTS WITH MULTI-ENGINE AND INSTRUMENT RATINGS PERFORMED A SIMULATED FLIGHT MISSION IN A GENERAL AVIATION TRAINER-2 (GAT-2) ON EACH OF TWO DAYS. THE EXPERIMENTAL CONDITIONS FOR THE GROUPS DIFFERED IN TERMS OF GAT-2 MOTION (GROUP I - NO MOTION), (GROUP II - SUSTAINED LINEAR, SCALED-DOWN ANALOG MOTION), (GROUP III - WASHOUT MOTION). EACH GROUP OF PILOTS THEN FLEW THE SAME MISSION IN A LIGHT TWIN-ENGINE AIRCRAFT REPRESENTATIVE OF THE CLASS OF AIRCRAFT SIMULATED BY THE GAT-2. THE EXPERIMENTAL DESIGN WAS A TWO FACTOR MIXED DESIGN (GROUPS BY DAYS) WITH REPEATED MEASURES ON ONE FACTOR (GROUPS).

THE MISSION CONSISTED OF FIVE MANEUVERS REPRESENTATIVE OF THOSE USUALLY PERFORMED UNDER INSTRUMENT FLIGHT RULES (IFR) WITHOUT VISUAL REFERENCE TO THE OUTSIDE WORLD AND FIVE MANEUVERS USUALLY PERFORMED WITH OUTSIDE VISUAL CONTACT UNDER VISUAL FLIGHT RULES (VFR). IN THE SIMULATOR, ALL OF THE MANEUVERS WERE PERFORMED WITHOUT OUTSIDE VISUAL REFERENCE.

TWO TRAINED OBSERVERS, ONE OF WHOM WAS ALSO THE SAFETY PILOT FOR THE MISSION, RECORDED PILOT PERFORMANCE ON EACH MISSION IN A SPECIALLY DESIGNED BOOKLET. THE ORDER OF ASSIGNMENT OF OBSERVERS TO THE MISSIONS PERMITTED RECORDING OF A PILOT'S PERFORMANCE ON A SINGLE MISSION BY TWO INDEPENDENT OBSERVERS AND ALSO THE RECORDING OF THE PILOTS PERFORMANCE ON TWO SUCCESSIVE MISSIONS BY THE SAME OBSERVER AND TWO INDEPENDENT OBSERVERS.

THE RESULTS INDICATED THAT THE PROFICIENCY OF AIRCRAFT PILOTS CAN BE PREDICTED TO A HIGH DEGREE FROM GROUND-BASED SIMULATOR PERFORMANCE MEASURES. OF THE THREE SIMULATOR MOTION CONDITIONS USED GREATER PREDICTION OF OPERATOR PERFORMANCE FROM A SIMULATOR TO FLIGHT CAN BE OBTAINED USING SUSTAINED COCKPIT MOTION THAN BY USING WASHOUT MOTION OR NO MOTION. THERE WAS NO SIGNIFICANT DIFFERENCE BETWEEN THE PREDICTIVE VALIDITIES OF PERFORMANCE WITH NO MOTION AND WASHOUT MOTION.

THE EXPERIMENT DEMONSTRATED THAT VERY HIGH OBSERVER-OBSERVER RELIABILITIES ($R=.771$ TO $.971$) ON THE SAME MISSION CAN BE OBTAINED BY RECORDING PERFORMANCE ON SCALES THAT ARE WELL DEFINED AND EASY TO FOLLOW, DESCRIPTIVE OF THE MANEUVER AND BEHAVIOR BEING RECORDED, AND NOT TOO DEMANDING UPON THE PERSON DOING THE RECORDING OF PERFORMANCE. THE PERFORMANCE MEASURES TAKEN IN THE SIMULATOR TENDED TO BE MORE RELIABLE THAN THOSE TAKEN IN THE AIRCRAFT BECAUSE OF THE ELIMINATION OF DEGRADING ENVIRONMENTAL FACTORS AND THE REDUCTION OF SAFETY ORIENTED DUTIES FREQUENTLY IMPOSED UPON SAFETY OBSERVERS.

SIMULATOR MOTION TENDS TO INCREASE SUBJECT ACCEPTABILITY OF THE DEVICE, LOWER PERFORMANCE ERROR SCORES, AND REDUCE THE WORK-LOAD ON THE SUBJECTS AND OBSERVERS THROUGH THE AIDING EFFECTS OF THE MOTION ONSET CUES. BUT THE DIFFERENTIAL EFFECTS OF MOTION ON TWO PERFORMANCE TRIALS IN THE SIMULATOR DO NOT TRANSFER TO PERFORMANCE IN FLIGHT. IN THE PREDICTION OF OPERATOR PERFORMANCE IN FLIGHT, THE MAGNITUDE OF THE ERROR SCORES RESULTING WITH THE USE OF ONE MOTION SYSTEM AS OPPOSED TO ANOTHER IS NOT AS IMPORTANT AS THE STABILITY OF THE SUBJECTS' PERFORMANCES FROM ONE DAY TO THE NEXT. INCREASING THE FIDELITY OF THE SIMULATOR MOTION SYSTEM MAY BRING MUCH OF THE VARIABILITY OF FLIGHT INTO THE SIMULATED ENVIRONMENT WHICH WAS USED TO ESCAPE THE VARIABILITY OF THE OPERATIONAL ENVIRONMENT.

THE RECORDED PILOT PERFORMANCE MEASURES CORRELATED VERY HIGHLY WITH THE OBSERVERS' OVERALL SUBJECTIVE RATINGS OF THE MISSIONS ($R=.725$ TO $.878$). THE OBSERVERS' OVERALL RATINGS CORRELATED SLIGHTLY HIGHER WITH PERFORMANCE ON INSTRUMENT FLIGHT MANEUVERS THAN WITH PERFORMANCE ON VISUAL FLIGHT MANEUVERS. OTHER POSSIBLE INDICIES OF PILOT PROFICIENCY, SUCH AS THE AMOUNT OF MULTI-ENGINE LAND, INSTRUMENT OR TOTAL FLIGHT TIME LOGGED IN THE PAST SIX MONTHS, DID NOT CORRELATE VERY WELL WITH MISSION PERFORMANCE SCORES. IN FACT, THEY CORRELATED ABOUT AS WELL AS AGE.

KRON, G.O. MOTION SIMULATION ENHANCEMENTS: THE DEVELOPMENT OF A RESEARCH G-SEAT SYSTEM. PROCEEDINGS OF THE SIXTH NTEC/INDUSTRY CONFERENCE, NAVTRAEGUIPCEN IH-226, NOVEMBER 13-15, 1973.

* ABSTRACT *

THIS REPORT CONTAINS OBSERVATIONS OF THE ASUPT RESEARCH G-SEAT PERFORMANCE WHICH ARE OF A PRELIMINARY NATURE. THE DOCUMENT IS A GOOD REFERENCE TO THE CONCEPT OF USING G-SEAT MECHANISMS FOR PRODUCING THE TYPE OF STIMULI RECOGNIZED BY THE SENSE OF TOUCH OR BODY FEEL (HAPTIC SENSORY SYSTEM). THE HAPTIC SYSTEM MEDIATES THE BODY FEEL OF MOTION AND THROUGH STIMULATION OF THIS SYSTEM BY MEANS OF COMPUTER-CONTROLLED CUSHION MOVEMENT, SUSTAINED ACCELERATION CUES MAY BE PRODUCED.

KRON, G.J. 'ADVANCED SIMULATION IN UNDERGRADUATE PILOT TRAINING: G-SEAT DEVELOPMENT'. SINGER SIMULATION PRODUCTS DIVISION FOR THE AIR FORCE HUMAN RESOURCES LABORATORY. REPORT NO. ASUPT-61 OCTOBER 1975, AD A017-468.

* ABSTRACT *

KINESTHETIC (SENSATION OF MOTION) CUES IN AIRCRAFT PILOT TRAINING SIMULATORS ARE GENERATED BY MOTION BASE SYSTEMS THAT STIMULATE THE VESTIBULAR AND SOMATIC, OR 'BODY FEEL' SENSORY SYSTEMS. THE NATURE OF THE SOMATIC SYSTEM SUGGESTS THAT IT MAY ALSO BE POSSIBLE TO STIMULATE THIS SYSTEM DIRECTLY BY EMPLOYING A SEAT WHOSE SHAPE VARIES AS A FUNCTION OF COMPUTED AIRCRAFT ACCELERATIONS. A RESEARCH FACILITY G-SEAT HAS BEEN DEVELOPED TO INVESTIGATE THIS METHOD OF STIMULATION USING A SIMULATED T-378 AIRCRAFT COCKPIT. DEVELOPMENT PHASE FINDINGS GERMANE TO THE PROBLEM OF DEVELOPING A SYSTEM SUITABLE FOR SOMATIC SYSTEM STIMULUS PRODUCTION AS WELL AS PRELIMINARY OBSERVATIONS CONCERNING THE ABILITY OF THIS SYSTEM TO INDUCE KINESTHETIC SENSATIONS ARE PRESENTED.

KRON, G.J. ADVANCED SIMULATION IN UNDERGRADUATE PILOT TRAINING: MOTION SYSTEM DEVELOPMENT. SINGER SIMULATION PRODUCTS DIVISION, BINGHAMTON FOR THE AIR FORCE HUMAN RESOURCES LABORATORY. REPORT NO. ASUPT-79, OCTOBER 1975, AD NO. A017 467

* ABSTRACT *

THE PRODUCTION OF KINESTHETIC INFORMATION PERTINENT TO THE AIRCRAFT PILOTING TASK BY USE OF MOTION BASE DEVICES RELIES ON MATHEMATICAL MODELS WHICH ARE DEVELOPED IN A LARGELY EMPIRICAL MANNER AND EVALUATED IN A SUBJECTIVE MANNER. THE ASUPT SIMULATOR CONTAINS A MOTION MATH MODEL WHICH IS DEVELOPED IN ANALYTICAL FASHION AND PERMITS BROAD LATITUDE FOR EXPERIMENTER INPUT TO ALTER OR DEGRADE THE RESULTANT MOTION INFORMATION. THIS PERMITS RESEARCH THAT IS USEFUL IN ESTABLISHING A RELATIONSHIP BETWEEN THE AMOUNT AND SCOPE OF MOTION INFORMATION AND TRAINING VALUE. THE MOTION SYSTEM EMPLOYED IN A 60 INCH SIX-DEGREE-OF-FREEDOM SYNERGISTIC SYSTEM. IT IS DRIVEN IN TRANSLATION BY A MODEL WHICH PERMITS PASSAGE OF ACCELERATION HINSET INFORMATION FOLLOWED BY CONTROLLED VELOCITY AND POSITION WASHOUT.

ROTATIONAL INFORMATION IS CONTROLLED BY DIGITALLY IMPLEMENTED CUE SHAPERS AND SUSTAINED TRANSLATION ACCELERATION SIMULATION IS MADE AVAILABLE BY SUBLIMINALLY TILTING THE MOTION SYSTEM PLATFORM TO CAUSE A PROJECTION OF THE GRAVITY VECTOR TO BE ALIGNED WITH THE SUSTAINED FORCE. THIS REPORT DISCUSSES THE IMPLEMENTATION OF THESE CONCEPTS, AND FORMS A FOUNDATION FOR UNDERSTANDING THE ASUPT MOTION SYSTEM COMPUTER PROGRAMS.

KRON, G.C., YOUNG, L AND ALBERY, W. HIGH G SIMULATION - THE TACTICAL AIRCRAFT SIMULATOR PROBLEM. PROCEEDINGS OF THE 1977 NTEC/INDUSTRY CONFERENCE, TECH REPORT: NAVTRAEGUIPCEN IH-294, NAV. 15-17, 1977.

* ABSTRACT *

THE PLATFORM MOTION SYSTEM HAS BEEN THE PRINCIPAL MOTION AND FORCE SIMULATION DEVICE IN THE PAST AND OVER THE LAST FIVE YEARS THE G-SEAT, G-SLIT, AND SEAT SHAKER SYSTEMS HAVE BECOME A PART OF SEVERAL OF THE AIR FORCE'S SIMULATORS. THIS PAPER PRESENTS THE BACKGROUND BEHIND THE DEVELOPMENT OF THESE DEVICES AND A DISCUSSION OF CURRENT AND FUTURE NON-VISUAL SYSTEM MOTION AND FORCE DEVELOPMENTS. THE CHALLENGE OF PROVIDING HIGH ACCELERATION CUES FOR THE TACTICAL AIRCRAFT SIMULATOR PILOT IS PRESENTED BY FIRST, LOOKING AT THE NEED FOR HIGH G SIMULATION AND SECOND LOOKING AT THE CURRENT DEVELOPMENT OF AN ADVANCED G-CUEING SYSTEM, HIGH G AUGMENTATION DEVICES, AND BIONIC MEANS FOR CONTROLLING SIMULATOR VISUAL DISPLAYS.

KUEHNEL, F.A. IN-FLIGHT MEASUREMENT OF THE TIME REQUIRED FOR A PILOT TO RESPOND TO AN AIRCRAFT DISTURBANCE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TECH. NOTE D-221, LANGLEY FIELD, VA, 3 NOV. 1959.

* ABSTRACT *

MEASUREMENTS OF THE TIME REQUIRED BY THE HUMAN PILOT TO DETECT AND INITIATE A CORRECTION FOR AN AIRPLANE DISTURBANCE HAVE BEEN MADE IN FLIGHT. THE PILOT'S TASK WAS TO CORRECT FOR AN APPLIED LATERAL OR LONGITUDINAL AIRPLANE DISTURBANCE AS RAPIDLY AS POSSIBLE. THE TIME LAPSE FROM THE START OF A DISTURBANCE TO THE START OF A PILOT CORRECTION WAS MEASURED FOR THREE PILOTS PERFORMING A TOTAL OF 51 DATA RUNS.

THE RESULTS OF THIS INVESTIGATION INDICATE THAT THE AVERAGE PILOT'S REACTION TIME FOR MODERATE TO LARGE LATERAL AIRPLANE DISTURBANCES IS 0.23 SECOND AND THAT THE AVERAGE REACTION TIME FOR MODERATE LONGITUDINAL AIRPLANE DISTURBANCES IS 0.33 SECOND.

THE PRESENT DATA SHOULD BE CONSIDERED AS MINIMUM PILOT REACTION TIMES OBTAINED WITH AN EXTREMELY ATTENTIVE PILOT WHICH MAY NOT NECESSARILY BE THE CASE IN AN OPERATIONAL SITUATION.

KUEHNEL, F.A.
HUMAN PILOT'S DYNAMIC RESPONSE CHARACTERISTICS MEASURED IN FLIGHT AND ON A NONMOVING SIMULATOR

NASA TN D-1229, MAR 1962,
AD-273 46C

* ABSTRACT *

AN INVESTIGATION HAS BEEN MADE IN FLIGHT AND ON A NONMOVING SIMULATOR TO DETERMINE THE DYNAMIC-RESPONSE CHARACTERISTICS OF HUMAN PILOTS CONTROLLING THE LONGITUDINAL RESPONSE OF AN AIRPLANE SUBJECT TO RANDOM-APPEARING DISTURBANCES. THE NON-MOVING SIMULATOR EMPLOYED THE COCKPIT AND CONTROL SYSTEM OF THE TEST AIRPLANE IN ORDER TO PROVIDE ENVIRONMENT AND CONTROL FORCE CHARACTERISTICS SIMILAR TO THOSE EXISTING IN FLIGHT. THE PILOTS' VISUAL STIMULI WERE SUPPLIED BY A PITCH-ATTITUDE-ERROR INDICATOR AND THE NATURAL HORIZON IN FLIGHT. FOUR FORMS OF THE INPUT DISTURBANCE AT TWO FLIGHT CONDITIONS CORRESPONDING TO FLIGHT DYNAMIC PRESSURES OF 76 AND 211 POUNDS PER SQUARE FOOT WERE INVESTIGATED. THE SAME INPUT SPECTRA AND SIMULATED FLIGHT CONDITIONS WERE INVESTIGATED DURING THE NONMOVING-SIMULATOR INVESTIGATION. IN ADDITION, A LIMITED NUMBER OF FLIGHT TESTS WERE MADE AT A THIRD FLIGHT CONDITION CORRESPONDING TO A DYNAMIC PRESSURE OF 225 POUNDS PER SQUARE FOOT.

DATA ARE PRESENTED IN THE FORM OF THE PILOTS' FREQUENCY RESPONSE AND THE POWER SPECTRAL DENSITY OF ERROR AND PILOT OUTPUT. SOME PRELIMINARY MATHEMATICAL EXPRESSIONS HAVE BEEN FITTED TO THE EXPERIMENTAL DATA.

THE RESULTS OF THIS INVESTIGATION INDICATE THAT THE CHARACTER OF THE PILOT'S FREQUENCY RESPONSE IS INFLUENCED BY THE TYPE OF INPUT DISTURBANCE, BY THE TYPE OF VISUAL ERROR DISPLAY, AND TO A LESSER EXTENT BY THE FLIGHT CONDITIONS OR DYNAMICS OF THE CONTROLLED ELEMENT, AT LEAST FOR THE RELATIVELY NARROW RANGE OF CONTROLLED-ELEMENT DYNAMICS COVERED. LITTLE DIFFERENCE BETWEEN THE RESPONSE CHARACTERISTICS OF DIFFERENT PILOTS OR OF THE SAME PILOTS ON DIFFERENT OCCASIONS HAVE BEEN NOTED FOR THE SAME TASK, BUT THE SAME PILOT WAS OBSERVED TO OPERATE IN A SIGNIFICANTLY DIFFERENT MANNER IN FLIGHT AND ON THE NONMOVING SIMULATOR. A BRIEF INVESTIGATION WAS MADE TO DETERMINE THE AIRPLANE-RESPONSE QUANTITY OF MOST IMPORTANCE TO THE PILOT IN A TRACKING TASK WITH A PITCH-ATTITUDE-ERROR INDICATOR. THE RESULTS INDICATE THAT THE PILOT'S CONTROL BEHAVIOR IS DEPENDENT PRIMARILY ON THE PITCH RESPONSE OF THE AIRPLANE AND IS NOT INFLUENCED BY THE NORMAL-ACCELERATION RESPONSE.

KURKOWSKI, R.L. ET. AL.
DEVELOPMENT OF TURBULENCE AND WIND SHEAR MODELS FOR SIMULATOR APPLICATION, NASA SP-270- MAY 4-6, 1971.

* ABSTRACT *

ATMOSPHERIC TURBULENCE AND WIND SHEARS CONTRIBUTE TO PILOTING PROBLEMS AND MAY LIMIT SAFE OPERATION OF AIRCRAFT. INVESTIGATIONS OF HANDLING AND CONTROL PROBLEMS IN ROUGH AIR AND WIND SHEAR CAN BE ACCOMPLISHED VERY EFFECTIVELY ON PILOT SIMULATORS BUT THIS REQUIRES GOOD MODELS OF THE ATMOSPHERIC DISTURBANCES.

THE PURPOSE OF THIS PAPER IS TO PRESENT INFORMATION ON SOME CONTINUING STUDIES AIMED AT PRODUCING REALISTIC MODELS OF TURBULENCE AND WIND SHEARS FOR HANDLING QUALITIES STUDIES. THESE STUDIES INCLUDE AN EVALUATION OF ANALYTICAL MODELS OF TURBULENCE WHICH HAVE NON-GAUSSIAN GUST DISTRIBUTIONS, A STATISTICAL ANALYSIS OF WIND SHEAR, AND A BRIEF EVALUATION OF THE EFFECTS OF WIND SHEAR ON AIRCRAFT OPERATIONS.

LACKNER, J.R. AND A. GRAYBIEL. SOME INFLUENCES OF TOUCH AND PRESSURE CUES ON HUMAN SPATIAL ORIENTATION. AVIAT. SPACE ENVIR. AN. MED. 49(6):798-804, 1978.

* ABSTRACT *

DURING CONSTANT VELOCITY ROTATION ABOUT HIS RECUMBENT Z AXIS, A BLINDED SUBJECT FEELS AS IF HE WERE ON AN ORBITAL PATH IN THE SAME DIRECTION. THIS EXPERIENCED MOTION RESULTS FROM THE PATTERN OF TOUCH AND PRESSURE STIMULATION OF THE BODY SURFACE. IF THE SUBJECT CHANGES THE PRESSURE PATTERN ON HIS BODY BY BRACING HIMSELF IN THE ROTATING APPARATUS IN DIFFERENT WAYS, IT IS POSSIBLE FOR HIM TO INFLUENCE PROFOUNDLY AND SYSTEMATICALLY HIS APPARENT ORIENTATION. FOR EXAMPLE, PRESSURE ON THE TOP OF HIS HEAD WHILE HE IS ROTATING CAN MAKE THE SUBJECT FEEL HE IS UPSIDE DOWN ON A CYLINDRICAL PATH. THE CHANGES IN APPARENT BRACING POSTURE ELICITED BY DIFFERENT PATTERNS OF PRESSURE CUES ARE VERY SIMILAR FOR DIFFERENT SUBJECTS AND ARE CONSTANT FOR THE SAME SUBJECT OVER TIME. DURING EXPERIENCED ORBITAL MOTION, A SUBJECT WILL HEAR A CONTINUOUSLY EMITTING SOUND SOURCE ONE THAT IS STATIONARY IN THE EXTERNAL ENVIRONMENT-AS CIRCLING HIS HEAD IN THE DIRECTION OPPOSITE THAT OF HIS TRUE ROTATION. IF THE ROTATING SUBJECT IS PERMITTED UNRESTRICTED SIGHT OF HIS SURROUNDINGS, HE NEITHER EXPERIENCES ORBITAL MOTION NOR MISLOCALIZES SOUNDS. THESE OBSERVATIONS PROVIDE INSIGHT INTO THE SPATIAL ORIENTATION MECHANISMS THAT NORMALLY ALLOW AN ORGANISM TO DISTINGUISH ACCURATELY BETWEEN THOSE CHANGES IN ACTIVITY AT ITS RECEPTORS CONTINGENT ON ITS OWN MOVEMENTS, AND THOSE RESULTING FROM MOVEMENT WITHIN THE ENVIRONMENT. THEY ALSO PROVIDE A WAY OF UNDERSTANDING SOME OF THE POSTURAL ILLUSIONS EXPERIENCED DURING EXPOSURE TO UNUSUAL FORCE ENVIRONMENTS, INCLUDING FREE FALL.

LAMONT, J.N. ANNOTATED BIBLIOGRAPHY OF FLIGHT SIMULATORS.
 TR-REF N9. 68 DIRECTORATE OF BIOSCIENCES RESEARCH, HUMAN RESOUR-
 CES RESEARCH SECTION, OTTAWA, CANADA. 1960. REF B U60-1524

* ABSTRACT *

THIS BIBLIOGRAPHY IS A LIST OF UNCLASSIFIED REPORTS, ARTICLES,
 AND OTHER MATERIAL REFERRING TO FLIGHT SIMULATORS. IT IS
 LIKELY TO BE OF USE TO SERVICE PERSONNEL WHO HAVE SOME
 RESPONSIBILITY IN CONNECTION WITH THE ACQUISITION, EVALUATION,
 AND USE OF THESE DEVICES FOR THE TRAINING OF AIRCRAFT PILOTS
 AND CREWS. SIMULATORS USED FOR OTHER PURPOSES, SUCH AS
 RESEARCH INTO PROBLEMS OF AIRCRAFT DESIGN OR THE TRAINING OF
 INDIVIDUAL CREW MEMBERS OTHER THAN THE PILOT, ARE NOT REFERRED
 TO HERE.

IN COLLECTING ITEMS FOR THE BIBLIOGRAPHY, THE COMPILER SEARCHED
 THE LITERATURE OF PSYCHOLOGY, EDUCATION AND TRAINING, BUT NOT
 OF ENGINEERING. HENCE THE EMPHASIS IS ON THE SIMULATOR AS A
 TRAINING DEVICE AND THE REFERENCES DEAL ONLY WITH THE UTILITY
 OF THE SIMULATOR IN CONTRIBUTING TO EFFECTIVE TRAINING, NOT
 WITH ITS MAINTAINABILITY NOR ITS COST, NOR ANY OTHER ASPECT OF
 ITS EFFECTIVENESS PURELY AS A PIECE OF ELECTROMECHANICAL
 EQUIPMENT.

LAL, C.G.Y., FORRUBIA, V., JENKINS, H.A., BALGH, R.W., AND
 YEE, R.C. LINEAR MODEL FOR VISUAL-VESTIBULAR INTERACTION.
 AVIAT. SPACE ENVIRON. MED. 49(7):880-885, 1978.

* ABSTRACT *

THE RESULTS OF EXPERIMENTS ARE EVALUATED IN TERMS OF A SIMPLE
 MODEL FOR THE INTERACTION OF EYE MOVEMENT RESPONSES TO SIMULTA-
 NEOUS OPTOKINETIC AND VESTIBULAR STIMULI. THE MODEL PREDICTIONS
 AGREE WITH THE RESULTS OF THESE EXPERIMENTS AND EXPLAIN MANY
 CLINICAL OBSERVATIONS CONCERNING THE EFFECT OF VISION ON NYSTAG-
 MUS. THE MODEL ACCOUNTS FOR THE DOMINANCE OF THE VISUAL SYSTEM'S
 RESPONSE OVER THE VESTIBULAR SYSTEM'S RESPONSE AT LOW FREQUEN-
 CIES. IT ALSO ACCOUNTS FOR THE INABILITY OF PATIENTS WITH DE-
 CREASED SMOOTH PURSUIT SYSTEM RESPONSE TO SUPPRESS THE VESTI-
 BULO-OCULAR REFLEX DURING SIMULTANEOUS OPTOKINETIC AND VESTIBU-
 LAR STIMULATIONS. THE MODEL PROVIDES USEFUL INFORMATION FOR THE
 DESIGN OF COMBINED OPTOKINETIC AND VESTIBULAR STIMULI TO TEST
 VESTIBULO-OCULAR REFLEXES.

LEATHERWOOD, J.D., DEMPSEY, T.K. AND CLEVENSON, S.A. AN EXPERI-
 MENTAL STUDY FOR DETERMINING HUMAN DISCOMFORT RESPONSE TO ROLL
 VIBRATION. NASA LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA.
 NASA TN D-8266, NOVEMBER 1976.

* ABSTRACT *

AN EXPERIMENTAL STUDY USING THE LANGLEY PASSENGER RIDE QUALITY APPARATUS (PRQA) WAS CONDUCTED TO DETERMINE THE SUBJECTIVE REACTIONS OF PASSENGERS TO ROLL VIBRATIONS. THE DATA OBTAINED ILLUSTRATE THE EFFECT UPON HUMAN COMFORT OF SEVERAL ROLL-VIBRATION PARAMETERS: NAMELY, ROLL-ACCELERATION LEVEL, ROLL FREQUENCY, AND SEAT LOCATION (I. E., DISTANCE FROM AXIS OF ROTATION). RESULTS OF AN ANALYSIS OF VARIANCE INDICATED THAT SEAT LOCATION HAD NO EFFECT ON DISCOMFORT RATINGS OF ROLL VIBRATIONS. THE EFFECT OF ROLL-ACCELERATION LEVEL WAS SIGNIFICANT, AND DISCOMFORT RATINGS INCREASED MARKEDLY WITH INCREASING ROLL-ACCELERATION LEVEL AT ALL ROLL FREQUENCIES INVESTIGATED. OF PARTICULAR INTEREST IS THE FACT THAT THE RELATIONSHIP BETWEEN DISCOMFORT RATINGS AND ROLL ACCELERATION LEVEL WAS LINEAR IN NATURE. THE EFFECT OF ROLL FREQUENCY ALSO WAS SIGNIFICANT AS WAS THE INTERACTION BETWEEN ROLL-ACCELERATION LEVEL AND ROLL FREQUENCY. THUS, THE PREDICTION OF DISCOMFORT RESPONSE TO ROLL VIBRATION REQUIRES KNOWLEDGE OF BOTH ROLL-ACCELERATION LEVEL AND ROLL FREQUENCY. OTHER INTERACTIONS OF THE ROLL PARAMETERS WERE NOT SIGNIFICANT.

LEVISON, W.H. AND JUNKER, A.M. A MODEL FOR THE PILOT'S USE OF MOTION CUES IN ROLL-AXIS TRACKING TASKS
AEROSPACE MEDICAL RESEARCH LABORATORY, AEROSPACE MEDICAL DIVISION, AIR FORCE SYSTEMS COMMAND, WRIGHT-PATTERSON AIR FORCE BASE
AFHS 45433 JUNE 1977 REPORT AMRL-TR-77-40

* ABSTRACT *

AN EXPERIMENTAL AND ANALYTICAL STUDY WAS UNDERTAKEN JOINTLY BY THE AEROSPACE MEDICAL RESEARCH LABORATORY AND BOLT BERANEK AND NEWMAN INC. TO TEST A MODEL FOR THE PILOT'S USE OF MOTION CUES IN ROLL-AXIS TRACKING TASKS. SIMULATED TARGET-FOLLOWING AND DISTURBANCE-REGULATIONS TASKS WERE EXPLORED WITH SUBJECTS USING VISUAL-ONLY AND COMBINED VISUAL AND MOTION CUES. THE EFFECTS OF MOTION CUES ON TASK PERFORMANCE AND PILOT RESPONSE BEHAVIOR WERE APPRECIABLE DIFFERENT FOR THE TWO TASK CONFIGURATIONS AND WERE CONSISTENT WITH DATA REPORTED IN EARLIER STUDIES FOR SIMILAR TASK CONFIGURATIONS. THE OPTIMAL-CONTROL MODEL FOR PILOT/VEHICLE SYSTEMS PROVIDED A TASK-INDEPENDENT FRAMEWORK FOR ACCOUNTING FOR THE PILOT'S USE OF MOTION CUES. SPECIFICALLY, THE AVAILABILITY OF MOTION CUES WAS MODELED BY AUGMENTING THE SET OF PERCEPTUAL VARIABLES TO INCLUDE POSITION, RATE, ACCELERATION, AND ACCELERATION-RATE OF THE MOTION SIMULATOR, AND RESULTS WERE CONSISTENT WITH THE HYPOTHESIS OF STRAIGHTFORWARD INFORMATIONAL MODEL ALLOWED ACCURATE MODEL PREDICTIONS OF THE EFFECTS OF MOTION CUES ON A VARIETY OF RESPONSE MEASURES FOR BOTH THE TARGET-FOLLOWING AND DISTURBANCE-REGULATION TASKS.

LEVISON, W.H. AND JUNKER, A.M. USE OF THE TILT CUE IN A SIMULATED HEADING TRACKING TASK. PRESENTED AT THE FOURTEENTH ANNUAL CONFERENCE ON MANUAL CONTROL, UNIVERSITY OF SOUTHERN CALIFORNIA, LOS ANGELES, CALIFORNIA, MAY 25-27, 1978.

* ABSTRACT *

AN EXPERIMENTAL AND ANALYTICAL STUDY WAS UNDERTAKEN JOINTLY BY THE AEROSPACE MEDICAL RESEARCH LABORATORY AND BOLT BERANEK AND NEWMAN INC. TO EXPLORE THE EFFECTS OF THE TILT CUE ON PILOT/VEHICLE PERFORMANCE IN A SIMULATED HEADING TRACKING TASK. THE TASK WAS PERFORMED WITH SUBJECTS USING VISUAL-ONLY CUES AND COMBINED VISUAL AND ROLL-AXIS MOTION CUES. HALF OF THE EXPERIMENTAL TRIALS WERE CONDUCTED WITH THE SIMULATOR ROTATING ABOUT THE HORIZONTAL AXIS; TO SUPPRESS THE TILT CUE, THE REMAINING TRIALS WERE CONDUCTED WITH THE SIMULATOR CAB TILTED 90 DEGREES SO THAT ROLL-AXIS MOTIONS WERE ABOUT EARTH VERTICAL.

THE PRESENCE OF THE TILT CUE ALLOWED A SUBSTANTIAL AND STATISTICALLY SIGNIFICANT REDUCTION IN PERFORMANCE SCORES. WHEN THE TILT CUE WAS SUPPRESSED, THE AVAILABILITY OF MOTION CUES DID NOT RESULT IN SIGNIFICANT PERFORMANCE IMPROVEMENT. THESE EFFECTS WERE ACCOUNTED FOR BY THE OPTIMAL CONTROL PILOT/VEHICLE MODEL, WHEREIN THE PRESENCE OR ABSENCE OF VARIOUS MOTION CUES WAS REPRESENTED BY APPROPRIATE DEFINITION OF THE PERCEPTUAL QUANTITIES ASSUMED TO BE USED BY THE HUMAN OPERATOR.

LEW, D. W., AND DYDA, K. J.
GROUND-BASED SIMULATION TECHNIQUES.
NORTH AMERICAN AVIATION INC., LOS ANGELES DIV., CALIFORNIA
FOR ILSA/VLABS REPORT, TR-67-56, AD-663 847, OCT 1967.

* ABSTRACT *

MANY METHODS HAVE BEEN USED TO CORRELATE GROUND-BASED SIMULATORS WITH THE ACTUAL AIRCRAFT THEY SIMULATE. COMPARISONS OF SIMULATION WITH FLIGHT IN PAST NAA/LAD PROGRAMS ARE PRESENTED. THEY INCLUDE DYNAMIC CHECKS, PERFORMANCE CHECKS, AND COMPARISONS AT THE STATISTICAL LEVEL. FAVORABLE COMPARISONS NOT ONLY VALIDATE THE PARTICULAR SIMULATOR INVOLVED BUT ALSO GIVE CREDENCE TO THE SIMULATION PROCESS FOR FUTURE SIMULATORS. GOOD CORRELATION BETWEEN SIMULATION AND FLIGHT CANNOT BE ATTRIBUTED TO ANY ONE SPECIFIC ITEM. THE OVERALL HANDLING AND FLYING CHARACTERISTICS ARE EMBODIED IN THE SIMULATION PROCESS, BUT IT IS THE ATTENTION TO DETAILS WHICH PRODUCE THE DISTINGUISHING CHARACTERISTICS OF A SPECIFIC AIRCRAFT. (AUTHOR)

LEWIS, S.T., WHITMORE, F.B., HARRIS, L. AND McDOUGALL, D. A SPATIAL DISORIENTATION DEMONSTRATOR. USAF SCHOOL OF AEROSPACE

MEDICINE, AEROSPACE MEDICAL DIVISION (AFSC), BROOKS AIR FORCE
BASE, TX, MAR 1965.

* ABSTRACT *

A SPATIAL DISORIENTATION DEVICE WAS DESIGNED AND CONSTRUCTED AT
THE REQUEST OF THE TACTICAL AIR COMMAND. THIS DEVICE IS
INEXPENSIVE, EASY TO OPERATE, AND PORTABLE. IT COMBINES THE
PRINCIPLES OF THE PARANY CHAIR AND CENTRIFUGE. THE PURPOSE OF
THIS REPORT IS TO DESCRIBE THIS USAFSAM SPATIAL DISORIENTATION
DEMONSTRATOR. (AUTHRS)

LEYMAN, C. AND NUTTALL, E.R. A SURVEY OF AIRCRAFT HANDLING CRITERIA.
MINISTRY OF AVIATION, AERONAUTICAL RESEARCH COUNCIL
CURRENT PAPER 1 C.P. 833, LONDON: HER MAJESTY'S STATIONERY
OFFICE, DEC. 1964

* ABSTRACT *

THIS NOTE DISCUSSES THE REQUIREMENTS FOR SATISFACTORY AND
MINIMUM ACCEPTABLE HANDLING QUALITIES OF AIRCRAFT. PUBLISHED
CRITERIA BASED ON VARIOUS SOURCES, E. G. VARIABLE STABILITY
AIRCRAFT AND FLIGHT SIMULATORS, ARE COMPARED AND SOME PRESENT
DAY AIRCRAFT EXAMINED IN THE LIGHT OF THE CRITERIA. IT IS
SHOWN THAT SOME MODIFICATION OF THE PUBLISHED CRITERIA IS
NECESSARY WHEN LARGE AIRCRAFT ARE CONSIDERED AND THAT THE
CRITERIA MUST IN ANY CASE BE USED WITH DUE REGARD TO THE FLIGHT
CONDITION AND AIRCRAFT ROLE UNDER CONSIDERATION. PART 1 GIVES
SOME BACKGROUND INFORMATION ON HANDLING RESEARCH AND DISCUSSES
PILOT PERCEPTION RATING SCALES. PARTS 2 AND 3 CONTAIN DETAILED
SURVEYS OF LONGITUDINAL AND LATERAL HANDLING CRITERIA
RESPECTIVELY. PART 4 DISCUSSES A THEORY OF HANDLING QUALITIES
BASED ON A SERVOMECHANICAL APPROACH AND PART 5 PRESENTS SOME
BROAD CONCLUSIONS. THE APPENDIX GIVES A SUMMARY OF THE
CONTENTS OF THE MORE IMPORTANT PUBLISHED WORKS ON HANDLING
QUALITIES. (AUTHOR)

LINCOLN, R.S. LEARNING A RATE OF MOVEMENT. J. OF EXPER.
PSYCHOL. 7, 1961, JUNE 1954, 456-470.

* ABSTRACT *

THIS EXPERIMENT WAS CONCERNED WITH ABILITY OF HUMAN S'S TO
LEARN A RATE OF MOVEMENT. THE RATE OF MOVEMENT WAS PRODUCED BY
TURNING A HANDWHEEL. THE RATE TO BE PRODUCED WAS DESCRIBED TO
DIFFERENT GROUPS OF S'S AS VARIOUS UNITS OF DISTANCE TO BE
TRAVELED IN 1 MIN. OF TIME. AFTER INITIAL ATTEMPTS TO PRODUCE
THE RATE, ALL S'S RECEIVED VERBAL DESCRIPTIONS OF THEIR AVERAGE
RATE ERROR. THIS INFORMATION WAS TO BE USED IN THE NEXT
ATTEMPT AT PRODUCING THE RATE. AT THIS TIME, ONE GROUP WAS

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ALSO PROVIDED WITH A CONTINUOUS VISUAL INDICATION OF RATE ERROR AS AN AID IN LEARNING THE RATE. RETENTION OF THE RATE OF MOVEMENT WAS EVALUATED IN A SERIES OF CRITERION TRIALS BY REQUIRING S'S TO PRODUCE THE RATE WITHOUT FURTHER ERROR INFORMATION. THE S'S THEN RELEARNED THE RATE OF MOVEMENT.

BEFORE ERROR INFORMATION WAS PROVIDED, S'S ENDED TO CRANK AT A RATE HIGHER THAN THE REQUIRED RATE. THIS TENDENCY INCREASED AS TRIALS PROGRESSED. THE EFFECT OF THE DIFFERENT RATE DESCRIPTIONS WAS NOT SIGNIFICANT.

WHEN CORRECTION INFORMATION WAS PROVIDED, ALL GROUPS SHOWED A RAPID INCREASE IN RATE ACCURACY. THE S'S WHO RECEIVED THE SAME TYPE OF VERBAL CORRECTIONS ACHIEVED AS HIGH A LEVEL OF ACCURACY AS THOSE S'S WHO WERE ALSO PROVIDED WITH THE VISUAL AID.

THE S'S WERE ABLE TO LEARN AND RETAIN THE RATE OF MOVEMENT. IN THE CRITERION TRIALS THE RATE WAS PRODUCED WITH MUCH GREATER ACCURACY THAN THAT OBTAINED IN THE PRELEARNING PERIOD. THE GROUP THAT WORKED WITH THE VISUAL AID SHOWED THE POOREST RATE ACCURACY WHEN FORCED TO DEPEND UPON KINESTHETIC CUES. THE EXTRA KNOWLEDGE OF RESULTS PROVIDED BY THE VISUAL AID WAS A DETRIMENT DURING THE CRITERION TRIALS.

THESE RESULTS APPEAR TO HAVE IMPLICATIONS FOR THE DESIGN OF TRAINING EQUIPMENT. IN ADDITION, THE RESULTS ALSO PROVIDE EVIDENCE THAT RATE ACCURACY IN HANDWHEEL CRANKING IS LIMITED BY THE NATURE OF ROTARY MOVEMENTS.

LINK, E.A. JR. - TRAINER FOR AVIATORS
PATENT NO. 2,099,857
FILED AUG. 14, 1936 GRANTED NOV. 23, 1937

NO ABSTRACT

LINK, E.A. ET AL - AVIATION TRAINER
PATENT NO. 2,358,016
FILED SEP. 9, 1942 GRANTED SEP. 12, 1944

NO ABSTRACT

LOWES, A.L., ELLIS, N.E., NORMAN, D.A. AND MATHENY, W.G.
IMPROVING PILOTING SKILLS IN TURBULENT AIR USING A SELF-ADAPTIVE
TECHNIQUE FOR A DIGITAL OPERATIONAL FLIGHT TRAINER. NAVTRADEVEN
67-C-0034-2, 1968, NAVAL TRAINING DEVICE CENTER, ORLANDO, FL.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE FEASIBILITY OF APPLYING ADAPTIVE PRINCIPLES TO FLIGHT SIMULATOR TRAINING FUNCTIONS. OF SPECIFIC IMPORTANCE WAS THE QUESTION: CAN AN OPERATIONAL FLIGHT TRAINER BE USED AS AN ADAPTIVE TRAINER TO IMPROVING PILOTING SKILLS. EIGHTEEN (18) NON-JET EXPERIENCED PILOTS WERE ASSIGNED TO TWO GROUPS FOR THE PURPOSE OF RECEIVING A CONSTANT AMOUNT OF FLIGHT SIMULATOR PRACTICE IN THE TASK OF MAINTAINING A CONSTANT ALTITUDE PROGRAM DURING SIMULATED AIR TURBULENCE. ONE GROUP WAS TRAINED USING AN ADAPTIVE TECHNIQUE AND THE OTHER GROUP WAS TRAINED UNDER CONDITIONS REPRESENTATIVE OF CONVENTIONAL TECHNIQUES. IT WAS HYPOTHESIZED THAT THE ADAPTIVELY TRAINED PILOTS WOULD BE MORE PROFICIENT WHEN TRANSFERRED TO A FLIGHT SIMULATION REPRESENTATIVE OF AN AIRCRAFT IN TURBULENT AIR THAN WOULD THE CONVENTIONALLY TRAINED PILOTS. RESULTING SUPPORTED THE HYPOTHESIS, AND IT WAS CONCLUDED THAT SELF-ADAPTIVE PRINCIPLES ARE FEASIBLE IN THE PERFORMANCE OF FLIGHT SIMULATOR TRAINING FUNCTIONS.

LUTHANDER, S. MOTION SYSTEM FOR A RESEARCH FLIGHT SIMULATOR: A PRELIMINARY DESIGN STUDY. STOCKHOLM. THE DIVISION OF AERONAUTICS, THE ROYAL INSTITUTE OF TECHNOLOGY, AUGUST, 1963.

ABSTRACT NOT AVAILABLE AT TIME OF PUBLICATION

LUTHANDER, STEEN. INVESTIGATION OF FUNCTION AND PERFORMANCE OF CAPIN MOTION SYSTEM OF FLIGHT TRAINING SIMULATOR FOR A/C 371, REPORT TA70C1-R2, 1968.

ABSTRACT NOT AVAILABLE AT TIME OF PUBLICATION

W. B. LUTON. SPACE FLIGHT ENVIRONMENTAL SIMULATOR
PATENT NO. 3,083,473
FILED JUNE 20, 1960 GRANTED APRIL 2, 1963

NO ABSTRACT

MACCHERLADALE, K. EFFECTS OF ANGULAR ACCELERATION AND CENTRIFUGAL FORCE ON NONVISUAL SPACE ORIENTATION DURING FLIGHT. JOURNAL OF AVIATION MEDICINE, JUNE 1948, 19, 146-157.

* ABSTRACT *

DATA WERE COLLECTED ON THE NONVISUAL PERCEPTION OF MOTION AND BODY POSITION DURING FLIGHT, ALL OBSERVATIONS BEING MADE WHILE AIRBORNE. THE SUBJECT WAS SEATED IN THE REAR COCKPIT OF AN ADVANCED NAVY TRAINER. THE MANEUVERS USED WERE LIMITED TO TURNS AT SIX ANGLES OF BANK. TWELVE OBSERVATIONS AT EACH ANGLE OF BANK WERE MADE BY EACH OF THREE EXPERIENCED OBSERVERS WITH VISUAL CUES EXCLUDED BY A BLACKOUT PROCEDURE. REPORTS OF THEIR PERCEPTIONS OF TURNING AND TILTING JUDGEMENTS OF THE DIRECTION (LEFT OR RIGHT) OF TURN AND TILT WHEN POSSIBLE, ESTIMATES OF DEGREES OF TILT FORWARD OR BACKWARD AND RIGHT OR LEFT IN DEGREES, AND ESTIMATES OF G FORCE WERE MADE VERBALLY BY THE OBSERVERS INTO A WIRE RECORDER. THESE REPORTS WERE LATER ANALYZED IN THE LABORATORY AND RELATED TO THE ACTUAL BEHAVIOR OF THE AIRCRAFT AS INDICATED ON THE SAME RECORD BY THE PILOT'S SIGNALS OF CRITICAL POINTS IN THE MANEUVER.

CONCLUSIONS

NONVISUAL SPATIAL ORIENTATION DURING FLIGHT IS SUBJECT BOTH TO GROSS LIMITATIONS AND TO ILLUSIONS. THE PERCEPTION OF TURNING AND TILTING TO THE RIGHT OR LEFT APPEARS AFTER A CONSIDERABLE LAG FROM THE ACTUAL ONSET OF THE MANEUVER. THE DIRECTION OF THE BANK AND TURN MAY BE IN ERROR, AND THE ESTIMATES OF THE AMOUNT OF BANK ARE MARKEDLY DEPRESSED. PERCEPTIONS OF BOTH TILTING AND TURNING ARE TRANSIENT, AND DISAPPEAR BEFORE THE PLANE RECOVERS FROM THE TURNING ATTITUDE. THE RECOVERY FROM THE TURNING ATTITUDE IS ACCOMPANIED BY SENSATIONS OF TILTING AND TURNING AWAY FROM THE DIRECTION OF THE PRECEDING TURN, WHICH PERSIST INTO THE PERIOD OF STRAIGHT AND LEVEL FLIGHT FOLLOWING A MANEUVER. THE ONSET OF TURN AND THE TURN PROPER ARE ACCOMPANIED BY SENSATIONS OF TILTING BACKWARD, WHICH PERSIST FOR THE DURATION OF THE TURN. FOLLOWING RECOVERY, THE OBSERVER FEELS HIMSELF TILTING FORWARD AFTER A BRIEF PERIOD OF FEELING UPRIGHT. THE PERCEPTIONS OF G PER SE ARE STRONG AND ACCURATE.

MACH, E. 'THE ANALYSIS OF SENSATIONS'. DOVER PUBLICATIONS: NEW YORK, 1959.

* ABSTRACT *

THIS BOOK BEGINS WITH A DISCUSSION OF THE RELATION OF PROBLEMS OF PSYCHOLOGICAL PERCEPTION TO CLASSICAL PHYSICS. IT PROCEEDS TO AN ANALYSIS OF FUNCTIONAL RELATIONS; THE SUPPOSED DUALISM OF THE PHYSICAL AND MENTAL; THE PRINCIPLE OF CONTINUITY, ITS INFLUENCE ON THE PROCESS OF LEARNING AND METHODS OF INVESTIGATION; THE THEORY OF COLOR SENSATIONS; CASUALITY AND TELEOLOGY; THE DIFFERENCE BETWEEN OPTICAL AND GEOMETRICAL SIMILARITY AND ITS SIGNIFICANCE; EVOLUTION OF THE SENSES; SPATIAL PERCEPTION, OPTICAL ILLUSIONS; THE SENSE OF BALANCE; THE WILL AS AN ORGANIC MANIFESTATION, VOLITION AND THE NERVOUS SYSTEM; INTERPOSITION OF

MIND BETWEEN IMAGES AND SENSATIONS; MEMORY; SENSATION OF TIME, TIME AND DREAMS; THE PSYCHOLOGY OF SOUND; AND CONTEMPORARY REACTIONS TO THESE IDEAS.

MACKIE, R.R., KELLEY, G.R., MBE, G.L. AND MECHERIKOFF, M. FACTORS LEADING TO THE ACCEPTANCE OR REJECTION OF TRAINING DEVICES. HUMAN FACTORS RESEARCH FOR THE NAVAL TRAINING EQUIPMENT CENTER, NAVTRAEQUIPCEN 70-C-026-1. AUGUST 1972.

* ABSTRACT *

THE USE AND ACCEPTANCE BY NAVY PERSONNEL OF 16 MAJOR TRAINING DEVICES WERE STUDIED IN RELATION TO: (1) SITUATIONAL FACTORS AFFECTING TRAINING; (2) SIMULATION CHARACTERISTICS OF THE TRAINER; (3) INSTRUCTIONAL CHARACTERISTICS OF THE TRAINERS; RELIABILITY OF THE TRAINERS; FORMAL AND INFORMAL COMMUNICATIONS REGARDING TRAINER CAPABILITIES; AND LEVEL OF EXPERIENCE OF THE USERS IN THE SYSTEMS SIMULATED BY THE TRAINERS. TRAINERS REPRESENTING AIR, SURFACE, AND SUBMARINE SYSTEMS WERE SELECTED FOR STUDY; THE PARTICIPANTS INCLUDED STUDENTS, INSTRUCTORS, ADMINISTRATIVE AND MAINTENANCE PERSONNEL.

AN ACCEPTANCE PROFILING TECHNIQUE WAS DEVELOPED THAT APPEARS TO BE HIGHLY DIAGNOSTIC OF THE REASONS FOR ACCEPTANCE OR REJECTION OF PARTICULAR TRAINERS. IT WAS EVIDENT THAT BOTH HIGHLY ACCEPTED AND SERIOUSLY REJECTED TRAINERS WERE REPRESENTED IN THE SAMPLE. METHODS FOR INCREASING TRAINER ACCEPTANCE ARE OUTLINED IN TERMS OF IMPROVEMENT IN SPECIFIC AREAS OF SIMULATION; IMPROVED SOFTWARE; GREATER QUALIFICATIONS FOR INSTRUCTORS; IMPROVED EVALUATION OF PERFORMANCE; AND IMPROVED UNDERSTANDING OF THE PURPOSE, CAPABILITIES AND LIMITATIONS OF TRAINERS BY THE USERS. THE MERITS OF CONTINUING STUDIES OF TRAINER ACCEPTANCE AND THE ROLE OF 'TRAINER ADVOCATE' ARE DISCUSSED.

PAGE 138, PARAGRAPH 9 - IF THE TRAINER DOES NOT REACT IN A FASHION VERY SIMILAR TO THE OPERATIONAL EQUIPMENT IT SIMULATES, IT IS CONSIDERED NONACCEPTABLE REGARDLESS OF WHETHER THE TRAINER WAS INTENDED TO BE A HIGH FIDELITY SIMULATOR OR NOT. ALTHOUGH IT MAY BE ACQUIRED IN SUCH A TRAINER, THE ATTITUDE OF 'RESPONSE SPECIFICITY' IS A MAJOR OBSTACLE TO ACCEPTANCE.

MAGID, E.B. AND COBERGMANN, R.R. HUMAN RESPONSE TO VIBRATION. IN BENNETT, E., DEGAN, J. AND SPIEGEL, J. (EDS.) HUMAN FACTORS IN TECHNOLOGY. HUMAN FACTORS SOCIETY, MCGRAW-HILL: NEW YORK 1963.

* ABSTRACT *

THE STUDIES DISCUSSED IN THIS CHAPTER DEMONSTRATE SIGNIFICANT MECHANICAL AND THEREFORE BIOLOGICAL PHENOMENA THAT LAST FOR

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RELATIVELY SHORT PERIODS OF TIME. IT HAS BEEN SHOWN THAT HUMAN BEINGS ARE ADVERSELY AFFECTED IN THE FREQUENCY RANGE OF 1 TO 20 CPS AND ARE PARTICULARLY VULNERABLE IN THE RANGE OF 1 TO 10 CPS. SUBJECTIVE RESPONSE (INCLUDING SEVERE PAIN) AND CARDIOVASCULAR, RESPIRATORY, SKELETAL-MUSCULAR, AND PERFORMANCE ALTERATIONS ARE AMONG THE VARIOUS EFFECTS OF THESE EXTRINSICALLY APPLIED ENVIRONMENTAL FORCES. IF THESE NOXIOUS FORCES ARE TO BE ENCOUNTERED, THE ACUTE AND CHRONIC EFFECTS ON THE HEALTH OF THE PASSENGER MUST BE ANTICIPATED. THESE OBSERVATIONS ARE THE RESULT OF INVESTIGATIONS OF CAREFULLY CONTROLLED SHORT-TIME STEADY-STATE SINUSOIDAL VERTICAL VIBRATIONS WITH A SPECIFIC SEATING AND RESTRAINT CONFIGURATION. IT IS NECESSARY TO EXTEND THIS WORK TO THE STUDY OF LONG-TERM STATES, INTERMITTENT BUFFETING, AND SINGLE REPETITIVE IMPACTS. ALSO NEEDED IS THE INVESTIGATION OF COMBINED MULTI-DIRECTIONAL FORCES WITH VARYING SEATING AND RESTRAINT SYSTEMS.

MALCIK, V.
PILOT ORIENTATION IN COMPLICATED METEOROLOGICAL CONDITIONS.
FOREIGN TECHNOLOGY DIV.
WRIGHT-PATTERSON AFB, OH
REPT. FTD-FT-23-372-68, AC-849-959,
JUL 1968.

* ABSTRACT *

THE PROBLEM OF COMBATING FLIGHT ILLUSION CONSISTS IN THE PILOT'S ABILITY TO IGNORE SENSATIONS IN HIS OWN BODY AND RELY COMPLETELY ON INSTRUMENTS FOR HIS CONTROL. BY IRRITATING HIS VESTIBULAR ORGANS THROUGH A GALVANIC CURRENT WHILE EXECUTING A GIVEN EXERCISE IN A FLIGHT SIMULATOR, WE EVOKE SENSATIONS ANALOGOUS TO ACTUAL FLIGHT ILLUSIONS. WE THUS PRODUCE EXPERIMENTALLY A SITUATION WHICH COMPRISES THE CHIEF FACTOR OF ILLUSION, CONFLICT BETWEEN SUBJECTIVE SENSATIONS, SUCH AS MAKING A TURN, AND OBJECTIVE INSTRUMENT READINGS WHICH INDICATE A STRAIGHT LINE OF FLIGHT. IF THE PILOT IGNORES HIS SUBJECTIVE SENSATIONS AND CONTINUES ACCORDING TO HIS INSTRUMENTS, HE MAINTAINS THE SET FLIGHT PATTERN. IF, ON THE OTHER HAND, HE SUBMITS TO ILLUSION AND IGNORES HIS INSTRUMENTS, HE MAKES AN IMPROPER MOVE WITH THE SIMULATOR CONTROLS AND DEVIATES FROM HIS COURSE. (AUTHOR)

MALLON, H.W. - AIRCRAFT TRAINING APPARATUS
PATENT NO. 2,357,481
FILED JUNE 5, 1943 GRANTED SEP. 5, 1944

NO ABSTRACT

MANN, CECIL W. AND RAY, J.T. THE PERCEPTION OF THE VERTICAL, XIV: THE EFFECT OF RATE OF MOVEMENT ON THE JUDGMENT OF THE VERTICAL. U.S.N. SCHOOL OF AVIATION MEDICINE RESEARCH REPORT, 1956, NM 001-110-500 REPORT NO. 40, 1-11.

* ABSTRACT *

AN EXPERIMENT WAS DESIGNED TO TEST THE EFFECT OF DIFFERENT RATES OF TILTING MOVEMENT UPON THE JUDGMENT OF THE POSTURAL VERTICAL IN THE ABSENCE OF VISUAL CUES. SUBJECTS WERE TILTED AT COMBINATIONS OF SPEEDS, DELAY AT THE TILTED POSITION, AND IN RIGHT AND LEFT QUADRANTS.

ANALYSIS OF VARIANCE OF THE CONSTANT ERRORS INDICATES THAT THE ERRORS OF JUDGMENT ARE SIGNIFICANTLY GREATER WHEN THE SUBJECTS ARE RETURNED TO THE VERTICAL AT SLOWER RATES OF MOVEMENT. IT IS SUGGESTED THAT THE PROBLEM OF DIFFERENTIAL ADAPTATION TO INCLINATION AS AN INFLUENCE UPON VERTICAL JUDGMENT SHOULD BE EXAMINED IN THE AIRPLANE UNDER CONDITIONS OF RELATIVELY RAPID AND RELATIVELY SLOW RETURN FROM A BANK TO A STRAIGHT AND LEVEL ATTITUDE.

MARTIN, E.L. AND WAAG, W.L. CONTRIBUTIONS OF PLATFORM MOTION TO SIMULATOR TRAINING EFFECTIVENESS: STUDY I - BASIC CONTACT. AFRL-TR-78-15. WILLIAMS AFB, AZ: FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, JUN 1978.

* ABSTRACT *

THE OBJECTIVE WAS TO EVALUATE THE CONTRIBUTIONS OF SYNERGISTIC SIX-DEGREE-OF-FREEDOM PLATFORM MOTION TO THE ACQUISITION OF BASIC CONTACT, APPROACH, AND LANDING SKILLS IN THE NOVICE PILOT. A TRANSFER-OF-TRAINING APPROACH WAS USED IN WHICH TWO GROUPS OF 1ST STUDENTS RECEIVED SIMULATOR PRETRAINING ON BASIC CONTACT, TAKEOFF, AND APPROACH AND LANDING TASKS EITHER WITH OR WITHOUT THE PRESENCE OF PLATFORM MOTION CUES. PERFORMANCE IN THE SIMULATOR AND SUBSEQUENT PERFORMANCE IN THE AIRCRAFT WAS MONITORED AND COMPARED WITH THE AIRCRAFT PERFORMANCE OF A CONTROL GROUP WHICH DID NOT RECEIVE ANY ADDITIONAL SIMULATOR PRETRAINING.

THE RESULTS OF THIS STUDY CLEARLY ESTABLISH THE POTENTIAL TRAINING VALUE OF NEW GENERATION GROUND-BASED TRAINERS. HOWEVER, THE DATA FAILED TO REVEAL ANY SIGNIFICANT OR PRACTICAL ENHANCEMENT OF TRAINING EFFECTIVENESS AS A RESULT OF THE ADDITION OF PLATFORM MOTION.

MATHENY, W.G. A STUDY OF COST FACTORS OF AIRCRAFT SIMULATION TO RELATE TRAINING COSTS TO TRAINING EFFECTIVENESS: (TRADER TV)

NAVTRAEQUIPCEN IH-298

LIFE SCIENCES, INC., JAN 7, 1963, SUBCONTRACT NO. HUMRRD-2-003.
(TRADER IV)

ABSTRACT NOT AVAILABLE AT TIME OF PUBLICATION

MATHEMY, W.G. 'STUDIES OF MOTION AND VISUAL INTERACTION IN SIMULATOR DESIGN AND APPLICATION'. LIFE SCIENCES, HURST, TEXAS FOR THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH. FINAL REPORT LSI-AFHSR-FR-76-1. SEPT. 1976.

* ABSTRACT *

THIS REPORT SUMMARIZES THE WORK UNDER CONTRACT F44620-73-C-0058 BETWEEN LIFE SCIENCES, INC., AND THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH. THE WORK WAS CONCERNED WITH STUDIES OF MOTION AND VISUAL INTERACTION IN SIMULATOR DESIGN AND APPLICATION. THE SPECIFIC OBJECTIVES OF THE WORK WERE: (1) DESCRIBE THE CHARACTERISTICS OF SIMULATOR MOTION AND VISUAL DISPLAY IN QUANTITATIVE TERMS AS EXPERIMENTAL VARIABLES; (2) DELINEATE MEASURES OF THE DEPENDENT VARIABLES IN TERMS OF SYSTEM OUTPUT AND PILOT INPUT MEASURES; (3) IDENTIFY AND ASSIGN PRIORITIES TO THE EXPERIMENTAL QUESTIONS AND FORMULATE AN OVER-ALL PLAN FOR THEIR INVESTIGATION; (4) DETERMINE THE CAPABILITY AND AVAILABILITY OF THE RESEARCH EQUIPMENT AVAILABLE FOR CARRYING OUT THE EXPERIMENTAL INVESTIGATIONS; AND (5) MAKE RECOMMENDATIONS FOR CARRYING OUT EXPERIMENTS BASED UPON CONSIDERATIONS OF PRIORITY AND RESEARCH EQUIPMENT CAPABILITY AND AVAILABILITY.

DUE TO THE LARGE NUMBER OF EXPERIMENTS INDICATED, EFFORT WAS CONCENTRATED ON THE DEVELOPMENT AND TESTING OF THE PERFORMANCE EQUIVALENCE METHOD FOR DETERMINING TRAINING SIMULATOR CHARACTERISTICS WHICH WOULD BE MORE ECONOMICAL OF TIME AND EFFORT. THIS METHOD PROPOSES THE COMPARISON OF THE SIMULATOR AND AIRCRAFT BASED UPON THE MEASURED PERFORMANCE OF THE PILOT IN TERMS OF CONTROL INPUTS TO THE TWO SYSTEMS BEING COMPARED. DATA WERE COLLECTED IN AN INSTRUMENTED T-37 TRAINING AIRCRAFT AS THE FIRST STEP IN CARRYING PILOT PERFORMANCE TO THAT IN THE ASUPT SIMULATION SYSTEM AT HUMAN RESOURCES LABORATORY FLYING TRAINING DIVISION, WILLIAMS AFB. DUE TO ADMINISTRATIVE AND SCHEDULING CONSTRAINTS IN COLLECTING THE AIRCRAFT DATA LEFT TIME IN THE CONTRACT FOR ONLY A PRELIMINARY ANALYSIS OF THESE DATA. EQUIPMENT AND SCHEDULING CONSTRAINTS ALLOWED FOR COLLECTION OF DATA IN ASUPT ON ONLY ONE PILOT FOR ONE FLIGHT.

PRELIMINARY ANALYSIS OF THE AIRCRAFT DATA INDICATE THAT THESE DATA CAN BE USED PROFITABLY IN THE DERIVATION OF MEASURES OF PILOT PERFORMANCE FOR TEST OF THE PERFORMANCE EQUIVALENCE CONCEPT. SINCE NO TIME REMAINED IN THE CONTRACT TO CARRY OUT PRELIMINARY ANALYSIS OF THE ASUPT DATA, NO PROJECTIONS CAN BE MADE AS TO THE ADEQUACY OF THESE DATA.

AN OVERALL PROGRAM OF RESEARCH ON THE MOTION-VISION AND THEIR INTERACTION PROBLEM WAS OUTLINED BASED UPON USE OF THE T-37 AIRCRAFT DATA AS A POINT OF DEPARTURE IN CONFIGURING ASUPT AS A CRITERION DEVICE. THE CARRYING OUT OF THE PLAN IF SUCCESSFUL WOULD PROVIDE QUICKER AND MORE ECONOMICAL ANSWERS TO BOTH SIMULATOR CHARACTERISTICS AND TRAINING METHODOLOGY QUESTIONS PROVIDED THE NECESSARY FUNDS AND PERSONNEL SUPPORT COULD BE BROUGHT TO BEAR ON THE PROBLEM. IT IS RECOMMENDED THAT THE PROGRAM BE PURSUED.

MATHERNY, W.G., DAUGHERTY, D.J. AND WILLIS, J.M. RELATIVE MOTION OF ELEMENTS IN INSTRUMENT DISPLAYS. 'AEROSPACE MEDICINE', NO. VEMBER 1963, PP. 1041-1046.

* ABSTRACT *

FROM EXPERIMENT NUMBER ONE IT IS EVIDENT THAT MOTION IS AN EXTREMELY RELEVANT VARIABLE IN THE EVALUATION OF DISPLAYS IN SITUATIONS IN WHICH MOTION CUES ARE PRESENT. THE RESULTS OF EXPERIMENT NUMBER TWO SUGGEST THAT IN CERTAIN SYSTEMS THE OPERATOR RECEIVES INFORMATION FROM HIS KINESTHETIC SENSES IN ADVANCE OF THAT RECEIVED THROUGHOUT THE VISUAL SENSE. TAKEN TOGETHER THE RESULTS FROM THESE EXPERIMENTS SUGGEST NOT ONLY THAT MOTION IS A RELEVANT VARIABLE, BUT THAT THE DEGREE TO WHICH IT DUPLICATES THE ANGULAR MOTIONS OF THE VEHICLE BEING SIMULATED IS MOST IMPORTANT. LACK OF THE MOTION CUES MAY LEAD TO ERRONEOUS CONCLUSIONS AS TO THE SUITABILITY OF DISPLAYS FOR SYSTEMS IN WHICH MOTION CUES ARE PRESENT. MOTION SIMULATION SYSTEMS, WHICH EXHIBIT TRANSIENT ACCELERATIONS OR UNREALISTIC PHASE DIFFERENCES BETWEEN MOTION AND VISUAL STIMULI, MAY PROVIDE CUES TO RESPONSE WHICH ARE INAPPROPRIATE TO THE TASK OF THE OPERATOR. SUCH FAULTS IN MOTION SIMULATION MAY BE EQUALLY SERIOUS FOR THOSE SITUATIONS IN WHICH THE SIMULATOR IS USED AS A TRAINING DEVICE AS FOR THOSE IN WHICH IT IS USED AS A DESIGN AND EVALUATION TOOL.

MATHERNY, W.G., GRAY, T.F. AND WATERS, B.K. CAPABILITIES IN UNDERGRADUATE PILOT TRAINING SIMULATION RESEARCH, EXECUTIVE SUMMARY. LIFE SCIENCES, FURST, TEXAS FOR THE AIR FORCE HUMAN RESOURCES LABORATORY. REPORT NO. LST-TR-75-2 AUGUST 1975, AD NH. AC17-168.

* ABSTRACT *

THIS REPORT DESCRIBES (1) THE RESEARCH CAPABILITIES OF AFHRL/FT WITH PARTICULAR EMPHASIS UPON THE ADVANCED SIMULATOR FOR UNDERGRADUATE PILOT TRAINING (ASUPT) (2) RESULTS OF A PRIORITIZATION OF POTENTIAL FLYING RESEARCH ISSUES BY A PANEL OF EXPERTS (3) CONTRACTOR RECOMMENDATION FOR INITIAL AFHRL/FT

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EXPERIMENTAL INVESTIGATIONS, AND (4) THE AFHRL/FT FACILITY UTILIZATION PROGRAM FOR CALENDAR YEAR 1975. THE CONCEPT OF PERFORMANCE EQUIVALENCE BETWEEN SIMULATOR AND AIRCRAFT IS PRESENTED ALONG WITH A DESCRIPTION OF SUGGESTED STUDIES DESIGNED TO VALIDATE THE CONCEPT. UTILIZATION OF AUTOMATED PERFORMANCE MEASURES ON BOTH SYSTEM OUTPUTS AND PILOT CONTROL INPUTS FORMS AN ESSENTIAL ELEMENT OF THE MODEL.

MATHENY, W.G., LOWES, A.L., BAKER, G. AND BYNUM, J.A. INVESTIGATION OF VISUAL, AURAL, MOTION AND CONTROL MOVEMENT CUES. LIFE SCIENCES INC. FOR THE NAVAL TRAINING DEVICE CENTER, NAVTRADEVCCEN TECHNICAL REPORT 69-C-0304-1, APRIL 1971.

* ABSTRACT *

THIS REPORT IS DEVOTED TO THE DETERMINATION OF HOW MULTI-SENSORY CUES CAN BE SIMULATED AND EFFECTIVELY USED IN THE TRAINING OF PILOTS. AN ANALYTICAL BASIS AND CUE TAXONOMY IS DEVELOPED AND CUES ARE POSTULATED ON THE BASIS OF INFORMATION GAINED FROM THE OUTSIDE VISUAL WORLD, FROM SOUNDS GENERATED BY THE AIRCRAFT, AND FROM CUES RESULTING FROM AIRCRAFT MOTION AND CONTROL MOVEMENTS. DESCRIPTION AND MEASUREMENT OF THE PHYSICAL CHARACTERISTICS OF THE POSTULATED CUES ARE EMPHASIZED. HYPOTHESES ARE DEVELOPED BASED UPON THE EFFECTS OF POSTULATED CUES AS THEY ARE BOTH FUNCTIONING INDEPENDENTLY AND INTERACT WITH CUES IN OTHER MODALITIES. EXPERIMENTATION IS RECOMMENDED WHICH WILL LEAD TO VERIFICATION OR MODIFICATION OF CUE POSTULATIONS.

MATHENY, W.G., LOWES, A.L. AND BYNUM, J.A. TO MOVE OR NOT TO MOVE THE PROBLEM OF MOTION IN TRAINING SIMULATORS. IN COMMEMORATIVE TECHNICAL JOURNAL, NAVAL TRAINING DEVICE CENTER 25TH ANNIVERSARY NAVTRADEVCCEN IH-223, NOVEMBER 1971.

* ABSTRACT *

IN THIS PAPER, AN EXAMINATION IS MADE OF THE TRAINEE PROBLEM IN AN ATTEMPT TO SORT OUT THE IMPORTANT VARIABLES, EXAMINE THE EVIDENCE AND DRAW CONCLUSIONS. THE QUESTION OF MOTION VS NO MOTION IS TAKEN UP AND WHERE TRAINER MOTION IS TO BE USED OR STUDIED, THE IMPORTANT PROBLEM OF THE QUANTITATIVE PHYSICAL DESCRIPTION OF THE TRAINER MOTION IS DISCUSSED IN SOME DETAIL. VARIABLES OF IMPORTANCE UPON WHICH THE UTILITY OF MOTION IS DEPENDENT ARE THE EXPERIENCE LEVEL OF THE TRAINEE, THE RESPONSE DYNAMICS OF THE VEHICLE BEING SIMULATED, THE MANEUVERS BEING PERFORMED AND THE VISUAL DISPLAYS BEING USED BY THE TRAINEE. THE INTERACTIVE EFFECT OF THESE VARIABLES WITH MOTION IS CONSIDERED.

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MATHEW, W.G., LOWES, A.L. AND BYNUM, J.A. 'AN EXPERIMENTAL INVESTIGATION OF THE ROLE OF MOTION IN GROUND-BASED TRAINERS'. LIFE SCIENCES, FURST, TEXAS FOR THE NAVAL TRAINING EQUIPMENT CENTER, REPORT NO. 71-C-CC75-1, APRIL 1974, AD NO. 778-665.

* ABSTRACT *

THE PURPOSE OF THE STUDY WAS TO PROVIDE DATA RELEVANT TO THE SPECIFICATION OF MOTION REQUIREMENTS FOR GROUND-BASED TRAINERS FOR AIRCRAFT PILOTS. THE STUDY INVESTIGATED THREE CATEGORIES OF MOTION: NO MOTION, MOTION CORRELATED WITH THE OUTPUT OF THE AIRCRAFT EQUATIONS AND VISUAL DISPLAYS, AND RANDOM UNCORRELATED MOTION. BOTH MAN-MACHINE SYSTEM OUTPUT MEASURES, AND OPERATOR OUTPUT MEASURES WERE USED AS MEASURES OF PERFORMANCE IN STUDYING THE EFFECTS OF THE EXPERIMENTAL CONDITIONS.

IT WAS CONCLUDED THAT UNCORRELATED MOTION IS EQUIVALENT TO NO MOTION SO LONG AS THAT MOTION IS OF RELATIVELY HIGH FREQUENCY, AND THAT IT IS QUESTIONABLE WHETHER USING MOTION SIMPLY AS A BREAKLOSS PHENOMENON IS WORTH THE EXTRA EXPENSE OF MOVING THE TRAINER.

WITH RESPECT TO CORRELATED MOTION, IT WAS FOUND THAT IT DIFFERS SIGNIFICANTLY FROM UNCORRELATED MOTION. ALTHOUGH THE PILOT'S CONTROL OF SYSTEM OUTPUT WAS THE SAME UNDER UNCORRELATED AND CORRELATED MOTION CONDITIONS, A DIFFERENT TECHNIQUE WAS USED BY THE PILOTS UNDER THE TWO CONDITIONS.

MATHEW, W.G. AND WILKERSON, L.E. FUNCTIONAL REQUIREMENTS FOR GROUND-BASED TRAINERS: MOTION CHARACTERISTICS. LIFE SCIENCES, INC. FT. WORTH, TEXAS, (FEBRUARY 1966)

* ABSTRACT *

IN THIS INVESTIGATION WE HAVE BEEN INTERESTED IN WHETHER ANY OF THE MOTION CHARACTERISTICS OF THE LIGHT TRAINING HELICOPTER COULD BE DISCRIMINATED BY THE PROPRIOCEPTIVE SENSES OF THE OPERATOR AND WHETHER THESE SENSATIONS COULD BE USED BY HIM AS INFORMATION SOURCES FOR CONTROL. IF SUCH CUES ARE FOUND TO BE PRESENT AND USEFUL, WE ARE INTERESTED IN EXAMINING THE EXTENT TO WHICH SIMULATION OF THESE MOTIONS IN A TRAINER MIGHT PROVE BENEFICIAL.

THE RESULTS ON THE LITERATURE LEAD TO THE CONCLUSION THAT THE MOTION OF THE HELICOPTER DOES PROVIDE A PHYSICAL STIMULUS WHICH IS DISCRIMINABLE BY THE OPERATOR AND USEFUL AS A CUE TO HIM IN EXERCISING CLOSED LOOP COMPENSATORY TRACKING CONTROL. ALTHOUGH DIRECT EMPIRICAL EVIDENCE IS NOT AVAILABLE, WE CONCLUDE THAT OTHER VIBRATORY MOTIONS OF THE HELICOPTER WHICH INDICATE THE DEVELOPMENT OF UNUSUAL FLIGHT CONDITIONS OR MALFUNCTIONS ARE DISCRIMINABLE BY THE OPERATOR AND CAN PROVIDE INFORMATION AS TO THE STATE OF THE AIRCRAFT IN ADVANCE OF VISUAL INDICATIONS.

WITH REGARD TO THE INCORPORATION OF MOTION INTO GROUND BASED TRAINING DEVICES FOR THE LIGHT TRAINING HELICOPTER, THE EVIDENCE INDICATED THAT TRAINING NOT ONLY PROCEEDS FASTER IN THE TRAINER BUT A GREATER AMOUNT OF TRANSFER IS OBTAINED WHEN THE TRAINER HAS INCORPORATED IN IT THE MOTIONS OF PITCH, ROLL, YAW, AND HEAVE. THE DECISION AS TO WHETHER MOTION SHOULD BE INCORPORATED INTO THE TRAINER, HOWEVER, MUST BE MADE IN THE LIGHT OF THE TRAINING PROGRAM IN WHICH IT WILL BE USED AND THE VARIOUS COSTS INVOLVED. FOR EXAMPLE, IT MAY BE ESTIMATED FROM THE DATA REPORTED BY PEDDERSEN (1962) THAT APPROXIMATELY SIX HOURS IN A FIXED BASE SIMULATOR PLUS SOME TWENTY MINUTES IN THE HELICOPTER WILL PRODUCE A LEVEL OF PROFICIENCY EQUIVALENT TO 4 1/2 HOURS IN A MOVING BASE SIMULATOR WITH APPROXIMATELY TEN MINUTES IN THE HELICOPTER. THIS SLIGHT ADVANTAGE OF THE MOTION PLATFORM MIGHT BECOME MUCH MORE ATTRACTIVE IF ONE CONSIDERS THE ADDITIONAL USE OF THE MOTION PLATFORM FOR TRAINING IN RECOGNITION OF VIBRATORY MOTIONS PECULIAR TO THE UNUSUAL OR MALFUNCTION STATES OF THE AIRCRAFT.

OUR EXAMINATION OF THE PROBLEM INDICATED THAT THE PITCH, ROLL, AND HEAVE MOTIONS SHOULD BE INCORPORATED INTO ANY MOTION PLATFORM. HOWEVER, UNTIL THE COSTS CAN BE REDUCED, THE YAW MOTION WOULD PROBABLY NOT BE WORTH ITS COST.

THE POSSIBILITY OF INTRODUCING MOTION CUES TO THE PILOT THROUGH MOTIONS OF THE PILOT'S SEAT RATHER THAN MOVING THE TOTAL CABIN WAS EXAMINED. THE FINDINGS ARE SUGGESTIVE THAT THIS METHOD OF IMPARTING MOTION CUES TO THE OPERATOR SHOULD BE GIVEN FURTHER EXPERIMENTAL INVESTIGATION SINCE IT OFFERS A MUCH MORE ECONOMICAL METHOD FOR INTRODUCING THESE CUES.

IF ONE IS TO INCORPORATE MOTION CUES INTO A GROUND BASED TRAINER, DECISIONS MUST BE REACHED AS TO THE CHARACTERISTICS OF THAT MOTION IN TERMS OF ITS ACCELERATIONS, RATES, AND DISPLACEMENTS. THE HYPOTHESIS IS ADVANCED THAT THE RATE OF ONSET OF ACCELERATION PROVIDES A SUFFICIENT CUE TO THE OPERATOR TO ASSIST HIM IN CLOSED LOOP TRACKING CONTROL; HOWEVER, THIS HYPOTHESIS SHOULD BE TESTED EXPERIMENTALLY. THE USE OF THE RATE OF ONSET OF ACCELERATION AS THE CUE TO THE OPERATOR WOULD PROVIDE CERTAIN ECONOMIC MOTION PLATFORM CONSTRUCTION.

IN TRAINERS INCORPORATING MOTION THE PIVOT POINT OF THE MOTION RELATIVE TO THE POSITION OF THE OPERATOR IS CONSIDERED TO BE IMPORTANT AND THIS PIVOT POINT SHOULD BE KEPT AS CLOSE TO THE ACTUAL PIVOT POINT IN THE VEHICLE BEING SIMULATED AS POSSIBLE.

THE PROBLEM OF MOTION CORRELATED WITH THE VISUAL DISPLAY INDICATIONS VERSUS MOVEMENT WHICH IS RANDOM, UNCORRELATED AND VIBRATORY IN NATURE WAS CONSIDERED. IN CORRELATED MOTION, THE PROPRIOCEPTIVE CUES ARE CORRELATED WITH THOSE RECEIVED BY THE VISUAL SENSES WHILE IN UNCORRELATED MOTION, THIS SYNCHRONIZATION IS NOT PRESENT. IN VIEW OF THE SUCCESS REPORTED BY DRENTZ (1958) IN USING A SIMULATOR INCORPORATING UNCORRELATED MOTION IN

THE TRAINING OF FRENCH HELICOPTER PILOTS AND THE SUBJECTIVE EVALUATION OF SUCH SYSTEMS BY THE AUTHORS, THE CONCLUSION SEEMS WARRANTED THAT A TRAINER WITH UNCORRELATED MOTION WHICH HAS PROPER SYSTEMS RESPONSE DYNAMICS WOULD PROVIDE A TRAINER FOR THE LIGHT HELICOPTER WHICH IS NEARLY OPTIMUM WITH RESPECT TO TRANSFER OF TRAINING AND COST. THE READER, HOWEVER, MAY FEEL AS DO THE AUTHORS THAT THESE CONCLUSIONS SHOULD BE CHECKED EXPERIMENTALLY BEFORE DECISIONS INVOLVING LARGE EXPENDITURES OF FUNDS ARE MADE.

 MATHEW, W.G. AND WILKERSON, L.E. FUNCTIONAL REQUIREMENTS FOR GROUND-BASED TRAINERS: HELICOPTER RESPONSE CHARACTERISTICS. LIFE SCIENCES FOR HUMRRB. HUMRRB TECHNICAL REPORT 70-17, OCTOBER 1970.

* ABSTRACT *

THE OVERALL RESEARCH PURPOSE WAS TO DEVELOP METHODS FOR ANALYZING THE HELICOPTER PILOT'S CONTROL TASKS, AS A BASIS FOR DECIDING CHARACTERISTICS NEEDED IN A GROUND-BASED TRAINER FOR USE IN PILOT TRAINING. THIS REPORT COVERS ONE PHASE, THE RESPONSE CHARACTERISTICS OF THE HELICOPTER AS IT REACTS TO CONTROL INPUTS AND EXTERNAL FORCES. ANALYSES WERE MADE OF (A) CHARACTERISTICS OF EACH DIMENSION OF CONTROL, (B) INTERACTION AMONG THE DIMENSIONS, (C) EFFECT OF EXTERNAL FORCING FUNCTIONS SUCH AS WIND, (D) INFORMATION THE PILOT RECEIVES BY KINESTHETIC FEEDBACK FROM THE CONTROLS. A MEASURE OF MAN-MACHINE SYSTEM CHARACTERISTICS WAS POSTULATED. THE EFFECTIVE TIME CONSTANT, THE TIME IT TAKES FOR THE DISPLAYED OUTPUT OF THE SYSTEM TO RISE ABOVE THE PILOT'S THRESHOLD OF PERCEPTION, DEALING WITH THE EFFECTS OF INTERACTION AMONG THE CONTROLS PROVED TO BE ONE OF THE MOST DIFFICULT. THE CHARACTERISTICS OF THE SYSTEM WERE IDENTIFIED IN SUCH A WAY THAT THEY CAN BE VARIED QUANTITATIVELY IN RESEARCH ON TASK DIFFICULTY AND TRANSFER OF TRAINING.

 MATTHEWS, N.G. THE RELATIVE IMPORTANCE OF PHYSIOLOGICAL AND VISUAL FACTORS IN PROVIDING REALISM IN FLIGHT SIMULATION. IN PROCEEDINGS TWO-DAY SYMPOSIUM ON FLIGHT TRAINING SIMULATORS FOR THE 70'S, 14TH/15TH OCTOBER 1970, ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 6BQ.

* ABSTRACT *

ABSTRACT (OF MOTION RELEVANT INFORMATION)

PHYSIOLOGICAL CUES ARE NORMALLY CONCERNED WITH THE REACTION OF THE PILOT TO THE FLIGHT OF THE AIRCRAFT. THESE ARE MAINLY MOTION CUES ASSOCIATED WITH ANGULAR AND TRANSLATIONAL MOTION.

AS GROUND BASED SIMULATOR TECHNIQUES HAVE MANY LIMITATIONS WE SHALL NOW CONSIDER SOME TYPICAL SIMULATION TASKS IN ORDER TO EMPHASIZE THE RELATIVE IMPORTANCE OF PHYSIOLOGICAL AND VISUAL CUES IN PROVIDING TRAINING IN THOSE TASKS.

1. PROCEDURE TRAINER - NO MOTION
2. INSTRUMENT TRAINER - BASIC MOTION SYSTEM NORMALLY EMPLOYED ATTEMPT FULL MOTION SIMULATION.
3. TAKE-OFF AND LANDING SIMULATOR - MOTION SYSTEMS OF HIGH FIDELITY WITH AT LEAST PITCH, ROLL AND HEAVE ARE NORMALLY USED.
4. LOW VISIBILITY LANDING SIMULATOR - MOTION REQUIREMENTS SIMILAR TO #3 EXCEPT ENGINE OUT CASE MAY NOT BE NEEDED.
5. ION ROUTE SIMULATOR - LIMITED MOTION AND VISUAL CUES ARE NECESSARY.
6. TACTICAL SIMULATOR - MOTION SYSTEMS WILL PROVIDE PITCH, ROLL AND HEAVE WITH EITHER SWAY OR YAW OR BOTH.
7. AIR-TO-AIR TARGET ATTACK SIMULATOR - MOTION REQUIREMENTS CAN BE IMPORTANT DUE TO THE HIGH RATE OF MANEUVER OF COMBAT AIRCRAFT.
8. VSTOL SIMULATORS - MOTION REQUIREMENTS DEPENDENT ON THE TYPE OF VEHICLE AND ITS MOTION CHARACTERISTICS BUT UP TO 5 DEGREES OF FREEDOM HAVE ALREADY BEEN USED.
9. SPACE-FLIGHT SIMULATOR - NO APPARENT MOTION IS EXPERIENCED IN SPACE, THE ESSENTIAL NEED IS FOR ABSOLUTE VISUAL REALISM.

MATTHEWS, N.B. AND MARTIN, C.A., CRANFIELD INSTITUTE OF TECHNOLOGY, CRANFIELD, BEDFORD.
THE DEVELOPMENT AND EVALUATION OF A 'IGI' SEAT FOR A HIGH PERFORMANCE MILITARY AIRCRAFT TRAINING SIMULATOR.
PRESENTED AT AGARD MEETING ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS, BELGIUM, 24-27 APRIL 1978.

* ABSTRACT *

WHILST THE OPINIONS OF THOSE INVOLVED COULD REFLECT GENERAL OPINION, IT IS KNOWN, USING 'EXPERIMENTAL TERMINOLOGY', THAT THE RELIABILITY OF RESULTS DETERMINED FROM A SMALL BIASED SAMPLE USING SUBJECTIVE METHODS OF MEASUREMENT IS VERY LOW. IN CONSEQUENCE, AN EVALUATION PROGRAMME WAS CARRIED OUT BY A SAMPLE OF TWENTY PILOTS FROM R.A.F. TRAINING AND OPERATIONAL SQUADRONS AND FROM FLIGHT TEST ESTABLISHMENTS. THE EVALUATION WAS CARRIED OUT USING SUBJECTIVE ASSESSMENTS IN CONJUNCTION WITH PILOT PERFORMANCE MEASUREMENTS. THE AIM OF THE ASSESSMENT WAS:

- (A) TO INVESTIGATE IF A 'IGI' SEAT OPERATING ON THE PRINCIPLE OF THE CRANFIELD 'IGI' SEAT WOULD HAVE TRAINING VALUE IN A FULL MISSION SIMULATOR.
- (B) TO DETERMINE AREAS IN WHICH THE SIMULATION WAS SATISFACTORY, INADEQUATE, OR EVEN INCORRECT.

NOTE, THE EVALUATION DID NOT ATTEMPT TO MEASURE TRAINING EFFECTIVENESS.

MAZER, M. THE G SUIT IN COMBAT. 'AIR SURGEON'S BULLETIN',
2:235, 1945

* ABSTRACT *

THE PURPOSE OF THIS PAPER WAS TO PRESENT DATA ON THE USE OF THE
G SUIT UNDER OPERATIONAL CONDITIONS IN THE EIGHTH AIR FORCE.

MCCALLEY, M.E., ROYAL, C.W., WYLIE, C.D., O'HANLON, J.F. AND
MACKIE, R.R. MOTION SICKNESS INCIDENCE: EXPLORATORY STUDIES OF
HABITUATION, PITCH AND ROLL, AND THE REFINEMENT OF A MATHEMATI-
CAL MODEL. HUMAN FACTORS RESEARCH, INC. FOR THE BIOLOGICAL SCI-
ENCES DIVISION, 'OFFICE OF NAVAL RESEARCH', ARLINGTON, VA, RPT
1733-2, APR 1976.

* ABSTRACT *

A SERIES OF EXPERIMENTS ON HUMAN SUBJECTS ASSESSED THE EFFECTS
OF PITCH AND ROLL AND HABITUATION ON MOTION SICKNESS INCIDENCE
(MSI). PITCH AND ROLL ANGULAR ACCELERATIONS, EVEN LARGER THAN
EXPECTED AT SEA, FAILED TO SYSTEMATICALLY INCREASE MSI. HABIT-
UATION WAS EVIDENCED IN SUSCEPTIBLE SUBJECTS WHO RECEIVED CON-
SECUTIVE DAILY 1-HOUR OR 2-HOUR EXPOSURES TO VERTICAL MOTION.
HABITUATION WAS GREATER FOR THE LONGER EXPOSURE AND THE MORE
SEVERE MOTIONS. A MATHEMATICAL MODEL DESCRIBING MSI AS A FUNC-
TION OF THE FREQUENCY AND ACCELERATION OF VERTICAL OSCILLATION
WAS REFINED BY INCLUDING EXPOSURE TIME AS AN INDEPENDENT VARI-
ABLE. INVESTIGATION OF FREQUENCIES OF OSCILLATION ABOVE .5 HZ
CONFIRMED THE PREDICTION OF THE MODEL THAT MSI CONTINUES TO DE-
CREASE AS A FUNCTION OF FREQUENCY FOR ALL FREQUENCIES GREATER
THAN APPROXIMATELY .16 HZ.

MCDONNELL, J.D. PILOT RATING TECHNIQUES FOR THE ESTIMATION AND
EVALUATION OF HANDLING QUALITIES. TECH. REPORT AFFDL-TR-68-76,
AIR FORCE FLIGHT DYNAMICS LABORATORY, AIR FORCE SYSTEMS COMMAND,
WRIGHT-PATTERSON AFB, OH, DEC. 1968.

* ABSTRACT *

ALTHOUGH RATING SCALES OF VARIED FORMS HAVE BEEN WIDELY USED TO
ESTIMATE AND EVALUATE HANDLING QUALITIES OVER THE PAST DECADE, A
NUMBER OF DEFICIENCIES IN BOTH METHOD AND DATA BASE HAVE BEEN
APPARENT. THIS INVESTIGATION WAS AIMED AT OVERCOMING MANY OF
THESE DEFICIENCIES BY ATTEMPTING TO RESOLVE THE DIFFICULTIES EX-
PERIENCED WITH RATING SCALES THEMSELVES, AND BY EXTENDING AND
ADDING TO ALREADY EXISTING RELATIONSHIPS BETWEEN RATINGS AND
PILOT/VEHICLE SYSTEM PARAMETERS.

RATING SCALES HAVE COME UNDER INCREASING CRITICISM FOR PROBLEMS SUCH AS WORDING AMBIGUITY, THE DUAL MISSION CHARACTER OF SOME SCALES, THE NONUNIFORMITY IN THE DISTRIBUTION OF DESCRIPTORS ACROSS THE SCALE, AND THE MISUSE OF SCALES WHICH HAS OCCURRED WHEN RATINGS HAVE BEEN AVERAGED. PSYCHOMETRIC METHODS PROVIDE AN APPROACH TO THESE PROBLEMS, AND IN THIS STUDY WERE USED TO SCALE SEVERAL PHRASES DESCRIPTIVE OF VEHICLE HANDLING QUALITIES. THUS, QUANTITATIVE CHARACTERISTICS WERE DERIVED FOR CONTEMPORARY SCALES THROUGH THE USE OF THE METHOD OF SUCCESSIVE INTERVALS. AN EXPERIMENT WAS CONDUCTED WHICH ADDED TO AVAILABLE DATA RELATING COOPER RATINGS AND PILOT/VEHICLE PARAMETERS, AND WHICH ALSO TESTED SOME POTENTIAL ALTERNATE SCALE CANDIDATES. THE CORRELATION RESULTS INDICATE THAT RATINGS ARE PROBABLY BASED ON PERFORMANCE AND THE DEGREE OF DIFFICULTY EXPERIENCED IN MAINTAINING THE PERFORMANCE. THE DIFFICULTY IS MOST EASILY REPRESENTED BY THE PILOT EQUALIZATION REQUIRED AND THE VEHICLE STICK CHARACTERISTICS.

 MCFARLAND, R.E. A STANDARD KINEMATIC MODEL FOR FLIGHT SIMULATION AT NASA-AMES. COMPUTER SCIENCES CORP., MOUNTAIN VIEW, CALIF. FOR NASA. NASA CR-2497, 1975.

* ABSTRACT *
 A STANDARD KINEMATIC MODEL FOR AIRCRAFT SIMULATION EXISTS AT NASA-AMES ON A VARIETY OF COMPUTER SYSTEMS, ONE OF WHICH IS USED TO CONTROL THE FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT (FSAA). THE DERIVATION OF THE KINEMATIC MODEL IS GIVEN AND VARIOUS MATHEMATICAL RELATIONSHIPS ARE PRESENTED AS A GUIDE TO INTERESTED FACILITY USERS. THESE INCLUDE DESCRIPTIONS OF STANDARDIZED SIMULATION SUBSYSTEMS SUCH AS THE ATMOSPHERIC TURBULENCE MODEL AND THE GENERALIZED SIX-DEGREES-OF-FREEDOM TRIM ROUTINE, AS WELL AS AN INTRODUCTION TO THE EMULATIVE BATCH-PROCESSING SYSTEM WHICH ENABLES THIS FACILITY TO OPTIMIZE ITS REAL-TIME ENVIRONMENT. (AUTHOR)

 MCGAUGH, M.F. AND HOLMAN, G.L. OPERATIONAL TEST II OF CH-47C SYNTHETIC FLIGHT TRAINING SYSTEM (2831) (SFTS). U.S. ARMY TRAINING AND DOCTRINE COMMAND, REPORT 2-36-7-6TN137-04, 31 OCTOBER 1977.

* ABSTRACT *
 THIS REPORT ADDRESSES OPERATIONAL ISSUES RELEVANT TO THE CH-47C SYNTHETIC FLIGHT TRAINING SYSTEM AS TESTED IN INSTITUTIONAL AND COMBAT READINESS FLYING ENVIRONMENTS. FINDINGS RELATED TO THE CAPABILITIES AND LIMITATIONS OF THE TEST ITEM EXAMINE SAFETY, INSTRUCTOR/OPERATOR TRAINING, THE AUTHENTICITY OF MOTION, VISUAL, AND SOUND SIMULATION, AND TRANSFER OF TRAINING FROM SIMULATOR TO AIRCRAFT. A CUMULATIVE TRANSFER EFFECTIVENESS

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RATIO OF .72 WAS CALCULATED FROM THE SIMULATOR TO THE AIRCRAFT IN THE INSTITUTIONAL ENVIRONMENT. THIS REPORT WILL BE USED TO FORMULATE A TRACAC POSITION FOR THE DEVELOPMENT ACCEPTANCE IN PROCESS REVIEW.

MCKEE, C.W. SINGLE-DEGREE-OF-FREEDOM SIMULATOR INVESTIGATION OF EFFECTS OF SUMMARY DISPLAY-INSTRUMENT SIGNALS ON MAN-MACHINE CONTROL. NASA 'TECHNICAL NOTE' D-148, LANGLEY RESEARCH CENTER, LANGLEY FIELD, VA., DEC. 1959

* ABSTRACT *

A LIMITED STUDY HAS BEEN MADE, USING ANALOG COMPUTING EQUIPMENT, OF A MAN'S ABILITY TO CONTROL 'ON INSTRUMENTS' AN INERTIA WITH A PROPORTIONAL ACCELERATION CONTROL. A SINGLE-DEGREE-OF-FREEDOM SYSTEM WAS SIMULATED, AND, AT TIMES, IN ORDER TO INCREASE THE DIFFICULTY OF THE TASK, UNREALISTIC DISTURBANCE INPUTS AND SYSTEM INSTABILITY WERE USED. THE STUDY WAS UNDERTAKEN TO EVALUATE PERFORMANCE OBTAINED WITH THE INDICATOR RESPONDING TO DISPLACEMENT AND WITH ANTICIPATION PROVIDED BY ADDING VELOCITY AND ACCELERATION SIGNALS TO THE INDICATOR.

THE SUMMING OF DISPLACEMENT AND VELOCITY SIGNALS IMPROVED PERFORMANCE AND HAD THE EFFECT OF PROVIDING SYSTEM DAMPING. THE ADDITION OF AN ACCELERATION SIGNAL WAS BENEFICIAL IN SOME INSTANCES BUT WAS DESTABILIZING IN THE ABSENCE OF A VELOCITY SIGNAL. (AUTHOR)

MCKEE, C.W. A THREE-AXIS FIXED-SIMULATOR INVESTIGATION OF THE EFFECTS ON CONTROL PRECISION OF VARIOUS WAYS OF UTILIZING RATE SIGNALS. NASA 'TECHNICAL NOTE' D-525, LANGLEY RESEARCH CENTER, LANGLEY FIELD, VA, JAN. 1961.

* ABSTRACT *

A THREE-AXIS VEHICLE CONTROL STUDY HAS BEEN MADE BY USE OF A FIXED SIMULATOR AND ANALOG COMPUTING EQUIPMENT, TO EVALUATE THE EFFECTS OF VARIOUS WAYS OF UTILIZING RATE INFORMATION. A SIDE-ARM CONTROLLER PROVIDING PROPORTIONAL ACCELERATION CONTROL WAS USED WITH A SIMULATED VEHICLE HAVING NO INHERENT STABILITY OR DAMPING. VEHICLE RATE SIGNALS WERE USED TO PROVIDE CONTROL FEEDBACK OR SYSTEM DAMPING AND WERE USED IN THE INSTRUMENT DISPLAY EITHER SEPARATE FROM OR SUMMED WITH DISPLACEMENT SIGNALS.

NEAR OPTIMUM PERFORMANCE OF BOTH TRANSITIONS IN ROLL AND CONTROL OF SYSTEM DISTURBANCE WAS OBTAINED BY USING A COMBINATION OF SYSTEM DAMPING AND SUMMED DISPLACEMENT SIGNALS AND RATE SIGNALS.

MCLANE, R.C. AND WIERWILLE, W.W.
THE INFLUENCE OF MOTION AND AUDIO CUES ON DRIVER PERFORMANCE
IN AN AUTOMOBILE SIMULATOR
HUMAN FACTORS, 1975, 17(5), 488-501

* ABSTRACT *

A HIGHWAY DRIVING SIMULATOR WITH A COMPUTER-GENERATED VISUAL DISPLAY, PHYSICAL MOTION CUES OF ROLL, YAW, AND LATERAL TRANSLATION, AND VELOCITY-DEPENDENT SOUND/VIBRATION CUES WAS USED TO INVESTIGATE THE INFLUENCE OF THESE CUES ON DRIVER PERFORMANCE. FORTY-EIGHT STUDENT SUBJECTS WERE RANDOMLY ALLOCATED TO SIX EXPERIMENTAL GROUPS. EACH GROUP OF EIGHT SUBJECTS EXPERIENCED A UNIQUE COMBINATION OF THE MOTION AND AUDIO CUES. THE CONTROL GROUP RECEIVED A FULL SIMULATION CONDITION WHILE EACH OF THE REMAINING FIVE GROUPS PERFORMED WITH CERTAIN COMBINATIONS OF MOTION AND SOUND DELETED. EACH DRIVER GENERATED NINE MINUTES OF CONTINUOUS DATA FROM WHICH FIVE PERFORMANCE MEASURES WERE DERIVED. RESULTS INDICATE THAT THE PERFORMANCE MEASURES OF YAW, LATERAL, AND VELOCITY DEVIATION ARE SIGNIFICANTLY AFFECTED BY THE DELETION OF CUES. IN SUPPORT OF THE HYPOTHESIS THAT DRIVER PERFORMANCE IS AUGMENTED BY THE ADDITION OF MOTION CUES, STATISTICALLY SIGNIFICANT NEGATIVE CORRELATIONS WERE OBTAINED BETWEEN THE NUMBER OF MOTION CUES PRESENT AND THE MEASURES OF YAW AND LATERAL DEVIATION. WITH RESPECT TO MOTION AND AUDIO CUES, RECOMMENDATIONS ARE MADE REGARDING SIMULATOR DESIGN CRITERIA.

MCLAUGHLIN, M.D. SIMULATOR INVESTIGATION OF MANEUVER SPEED INCREASES OF AN SST CONFIGURATION IN RELATION TO SPEED MARGINS.
NASA TECHNICAL NOTE, D-4085, 'LANGLEY RESEARCH CENTER', LANGLEY STATION, HAMPTON, VA, OCT. 1967.

* ABSTRACT *

A PRELIMINARY INVESTIGATION HAS BEEN MADE OF AIRSPEED INCREASES FROM UPSETS IN PITCH, PUSH-OVERS, LONGITUDINAL TRIM RUNAWAYS, AND ABANDONS OF CONTROLS AND SIMULATED OPERATIONS IN THE AIR TRAFFIC CONTROL (ATC) SYSTEM FOR A GENERALIZED DOUBLE-DELTA SUPERSONIC TRANSPORT (SST) CONFIGURATION FOR THE PURPOSE OF ASSESSING THE OVERSPEEDING IN RELATION TO THE TENTATIVE SPEED MARGIN. A PILOTED FIXED-BASE AIRCRAFT SIMULATOR WAS USED IN THE INVESTIGATION. TESTS WERE MADE FOR CLIMB, LEVEL FLIGHT, AND DESCENT CONDITIONS ALONG THE MAXIMUM OPERATING LIMIT SPEED PROFILE. RESULTS SHOW THAT AT SUPERSONIC SPEEDS THE 7.5 DEGREE UPSET MANEUVER, CURRENTLY PROPOSED AS A STANDARD FOR ESTABLISHING A SPEED MARGIN, PROVIDED A MARGIN GREATER THAN THE SPEED EXCURSIONS RESULTING FROM OTHER MANEUVERS. THE 7.5 DEGREE UPSET MANEUVER, HOWEVER, MAY BE UNSUITABLE FOR ESTABLISHING OVERSPEED CRITERIA FOR THE SST AT SUPERSONIC SPEEDS BECAUSE OF THE INCREASE IN ENTRY TIMES OVER SUBSONIC VALUES. A CONSTANT

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ACCELERATION PUSH-OVER TYPE OF MANEUVER APPEARED TO BE MORE RATIONAL AT SUPERSONIC SPEEDS. IN OPERATIONS IN THE SIMULATED ATC SYSTEM, THE PILOTS RECOMMENDED THAT, IN ORDER TO AVOID FREQUENT OVERSPEEDS, THE CLIMB PROFILE SHOULD BE A MINIMUM OF AT LEAST 10 TO 20 KNOTS BELOW THE MAXIMUM OPERATING LIMIT SPEED.

MCLEAN, A. THE USE OF FLIGHT SIMULATION IN THE DEVELOPMENT OF THE SAAB AJ 37 VIGGEN SYSTEM. VORTAG, OFFIZIER ALF DEM VII. ICAS KONGRES, ROM, SEP 1970.

* ABSTRACT *

IN ORDER TO AVOID PILOT INDUCED OSCILLATION (PIO) TENDENCIES, INVESTIGATIONS WERE CONDUCTED OVER A WIDE RANGE OF STICK FORCE AND STICK PATH PER G. THE EFFECTS OF THESE PARAMETERS ON THE PILOT EVALUATION OF THE 'HANDLING QUALITIES' IN THE LONGITUDINAL DIRECTION WERE STUDIED. FOR COMPARISON PURPOSES, FLIGHTS WERE CARRIED OUT WITH AND WITHOUT COCKPIT MOTION. DURING THESE SIMULATIONS NO NOTICEABLE DIFFERENCES WERE FOUND AT THE EIGEN FREQUENCIES BETWEEN 0.2 TO 0.7 HZ. AT AN EIGEN FREQUENCY OF 1.2 HZ THERE WERE SIGNIFICANT DIFFERENCES, AT LEAST FOR INCREASED STICK SENSITIVITY.

INVESTIGATIONS OF THE PRIMARY FLIGHT CONTROL SYSTEMS WERE CARRIED OUT AT SAAB USING A FIVE DEGREES OF FREEDOM PROGRAM (V=CONST) WITHOUT COCKPIT MOTION. THERE WAS AGREEMENT BETWEEN PILOT EVALUATIONS IN THE SIMULATOR AND DURING FLIGHT. THIS WAS SHOWN FOR FIVE DIFFERENT FLIGHT MODES IN THE FIGHTER CONFIGURATION. HOWEVER, THIS AGREEMENT CANNOT BE REACHED IF FAR M=0.9 IN THE VICINITY OF THE GROUND, THE STICK SENSITIVITY IS INCREASED UNTIL PIO TENDENCIES APPEAR. IN THIS CASE, REALISTIC EVALUATIONS CAN ONLY BE OBTAINED WITH MOTION SIMULATION.

MELF, M.F. BIBLIOGRAPHY ON TRACKING CONTROLS. MEASUREMENT SYSTEMS, INC., NORWALK, CONNECTICUT, JUL 1967.

* ABSTRACT *

A BIBLIOGRAPHY OF 371 REFERENCES ON TRACKING.

METRY, C.L. THE VESTIBULAR SYSTEM AND HUMAN DYNAMIC SPACE ORIENTATION. (TECHNICAL REPORT NASA CR-628), MIT, MAN-VEHICLE CONTROL LAB., THESIS NO. T-65-1, JUN 1965.

* ABSTRACT *

THE MOTION SENSORS OF THE VESTIBULAR SYSTEM ARE STUDIED TO

DETERMINE THEIR ROLE IN HUMAN DYNAMIC SPACE ORIENTATION AND MANUAL VEHICLE CONTROL. THE INVESTIGATION YIELDED CONTROL MODELS FOR THE SENSORS, DESCRIPTIONS OF THE SUBSYSTEMS FOR EYE STABILIZATION, AND DEMONSTRATIONS OF THE EFFECTS OF MOTION CUES ON CLOSED LOOP MANUAL CONTROL.

EXPERIMENTS ON THE ABILITIES OF SUBJECTS TO PERCEIVE A VARIETY OF LINEAR MOTIONS PROVIDED DATA ON THE DYNAMIC CHARACTERISTICS OF THE OTOLITHS, THE LINEAR MOTION SENSORS. ANGULAR ACCELERATION THRESHOLD MEASUREMENTS SUPPLEMENTED KNOWLEDGE OF THE SEMI-CIRCULAR CANALS, THE ANGULAR MOTION SENSORS. MATHEMATICAL MODELS ARE PRESENTED TO DESCRIBE THE KNOWN CONTROL CHARACTERISTICS OF THE VESTIBULAR SENSORS, RELATING SUBJECTIVE PERCEPTION OF MOTION TO OBJECTIVE MOTION OF A VEHICLE.

THE VESTIBULAR SYSTEM, THE NECK ROTATION PROPRIOCEPTORS AND THE VISUAL SYSTEM FORM PART OF THE CONTROL SYSTEM WHICH MAINTAINS THE EYE STATIONARY RELATIVE TO A TARGET OR A REFERENCE. THE CONTRIBUTION OF EACH OF THESE SYSTEMS WAS IDENTIFIED THROUGH EXPERIMENTS INVOLVING HEAD AND BODY ROTATIONS ABOUT A VERTICAL AXIS. COMPENSATORY EYE MOVEMENTS IN RESPONSE TO NECK ROTATIONS WERE DEMONSTRATED AND THEIR DYNAMIC CHARACTERISTICS DESCRIBED BY A LAG-LEAD MODEL. THE EYE MOTIONS ATTRIBUTABLE TO NECK ROTATIONS AND VESTIBULAR STIMULATION OBEY SUPERPOSITION WHEN BOTH SYSTEMS ARE ACTIVE.

HUMAN OPERATOR COMPENSATORY TRACKING IS INVESTIGATED IN SIMPLE VEHICLE ORIENTATION CONTROL SYSTEMS WITH STABLE AND UNSTABLE CONTROLLED ELEMENTS. CONTROL OF VEHICLE ORIENTATION TO A REFERENCE IS SIMULATED IN THREE MODES: VISUAL, MOTION, AND COMBINED. MOTION CUES SENSED BY THE VESTIBULAR SYSTEM AND THROUGH TACTILE SENSATION ENABLE THE OPERATOR TO GENERATE MORE LEAD COMPENSATION THAN IN FIXED BASE SIMULATION WITH ONLY VISUAL INPUT. THE TRACKING PERFORMANCE OF THE HUMAN IN AN UNSTABLE CONTROL SYSTEM NEAR THE LIMITS OF CONTROLLABILITY IS SHOWN TO DEPEND HEAVILY UPON THE RATE INFORMATION PROVIDED BY THE VESTIBULAR SENSORS.

MEIRY, JACOB L.

MIT CAMBRIDGE

70-349

MOTION CUES - WHEN AND WHY AIAA CONF MAR 16-18 1970 (CAPE)

* ABSTRACT *

DAILY HUMAN ACTIVITY INCLUDES COMPLEX ORIENTATION, POSTURAL CONTROL, AND MOVEMENT COORDINATION. ALL THESE TASKS DEPEND UPON MAN'S PERCEPTION OF MOTION. THE VESTIBULAR SYSTEM IS RECOGNIZED AS THE PRIME MOTION SENSING CENTER IN THE HUMAN. AUGMENTED BY TACTILE AND VISUAL INFORMATION, THE PERCEPTION OF MOTION BY THE VESTIBULAR SENSORS IS USED IN MAN'S ORIENTATION IN THREE-DIMENSIONAL SPACE. MAN-MADE VEHICLES HAVE EXTENDED THE

OPERATING ENVIRONMENT OF MAN AND THEREBY DELEGATED NEW RESPONSIBILITIES TO HIS SENSORY SYSTEM. ILLUSORY PERCEPTION, EYE MOVEMENTS, AND DESCRIBING FUNCTIONS OF THE HUMAN OPERATOR ARE DISCUSSED IN LIGHT OF THE MODELS OF THE VESTIBULAR SENSORS. A TABULATION OF WHETHER AND HOW TO SIMULATE MOTION INPUTS IS OUTLINED AND EXPERIMENTAL RESULTS ARE BROUGHT TO ILLUSTRATE THE SIGNIFICANCE OF MOTION INPUTS IN VEHICLE CONTROL.

MENDLA, D.K. RECENT EXPERIENCES WITH A FIXED BASE SIMULATOR IN THE INVESTIGATION OF HANDLING AND PERFORMANCE PROBLEMS OF THE V.T.O.L. TRANSPORT AIRCRAFT. 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE PAPER' 70-345, CAPE CANAVERAL, FL, MAR 16-18, 1970.

* ABSTRACT *
IN ORDER TO EXPLORE THE HANDLING AND PERFORMANCE QUALITIES OF A FUTURE CIVIL V.T.O.L. AIRCRAFT, SOME FAIRLY EXTENSIVE FLIGHT SIMULATION TRIALS HAVE BEEN CARRIED OUT BY HAWKE, SIDDLEY AVIATION USING THE COMPANY'S FIXED BASE SIMULATOR WITH AN ALL ELECTRONICALLY GENERATED VISUAL DISPLAY.

THE SIMULATOR FLIGHT DECK WAS EQUIPPED WITH THE CONVENTIONAL DIAL FLYING CONTROLS AND INSTRUMENT PANELS TYPICAL OF CURRENT JET AIRLINERS, BUT WITH SOME MINOR MODIFICATIONS TO SUIT THE V.T.O.L. ROLE. ENGINE CONTROLS WERE ALSO MODIFIED AS NECESSARY, AND A SIMPLE HEAD-UP DISPLAY WAS INCORPORATED. AN ANALOG COMPUTER HAVING SOME 400 AMPLIFIERS WAS USED, GIVING SUFFICIENTSophistication FOR SOLVING THE EQUATIONS OF MOTION IN SIX DEGREES OF FREEDOM.

TEST PILOTS WITH CURRENT JET V.T.O.L. AIRCRAFT AND HELICOPTER FLYING EXPERIENCE PARTICIPATED IN THE PILOTTED TRIALS, BEFORE WHICH THE SIMULATOR WAS CALIBRATED BY SIMULATING FIRST, A KNOWN JET V.T.O.L. AIRCRAFT. A CLOSE REPRESENTATION OF SUCH AN AIRCRAFT WAS ACHIEVED WITHIN THE LIMITATIONS OF THE FIXED BASE SIMULATOR USED. CONFIDENCE WAS THUS GAINED IN THE METHOD AND IN THE INTERESTING RESULTS OBTAINED, WHICH ARE DESCRIBED IN SOME DETAIL IN THIS PAPER. (AUTHOR)

MEYER, D.E., FLEXMAN, R.E., VAN GUNDY, E.A., KILLIAN, D.E. AND LANAHAN, C.J. 'A STUDY OF SIMULATOR CAPABILITIES IN AN OPERATIONAL TRAINING PROGRAM'. WRIGHT PATTERSON AFB, OHIO: AEROSPACE MEDICAL RESEARCH LABORATORY, TECHNICAL REPORT AMRL-TR-67-14, MAY 1967.

* ABSTRACT *
THE EXPERIMENT WAS CONDUCTED TO DETERMINE THE EFFECTS OF SIMULATOR TRAINING TO CRITERION PROFICIENCY UPON TIME REQUIRED

IN THE AIRCRAFT. DATA WERE ALSO COLLECTED ON PROFICIENCY LEVELS ATTAINED, SELF-CONFIDENCE LEVELS, INDIVIDUAL ESTIMATES OF CAPABILITY AND SOURCES FROM WHICH THAT CAPABILITY WAS DERIVED. SUBJECTS FOR THE EXPERIMENT WERE 48 AIRLINE CAPTAINS TRANSITIONING INTO THE DC-8 AIRCRAFT. THE SUBJECTS WERE EQUALLY ASSIGNED TO EXPERIMENTAL AND CONTROL TREATMENT GROUPS. SUBJECTS IN THE EXPERIMENTAL GROUP WERE TRAINED IN THE DC-8 SIMULATOR FOR AS MUCH TIME AS REQUIRED TO SATISFY THEIR INSTRUCTORS THAT THEY COULD PERFORM THE REQUIRED MANEUVERS IN THE SIMULATOR AT THE SAME LEVEL OF PROFICIENCY REQUIRED TO PASS THE FINAL QUALIFICATIONS CHECK IN THE AIRCRAFT. THE CONTROL GROUP WAS TRAINED USING THE STANDARD CURRICULA WHICH REQUIRED A FIXED TIME IN THE SIMULATOR. DATA OBTAINED FROM STUDENT REACTIONS TO QUESTIONNAIRE ITEMS ARE INTERPRETED TO INDICATE THAT: (1) SIMULATORS CAN BE USED TO FURTHER REDUCE REQUIREMENTS FOR TRAINING TIME IN AIRCRAFT AND (2) SIMULATORS CAN BE USED TO EVALUATE PERFORMANCE THAT IS INDICATIVE OF PERFORMANCE IN THE AIRCRAFT.

MIDDLETON, D.B., HURT, G.J., BERGERON, H.P., PATTON, J.M., DEAL, P.L. AND CHAMPINE, R.A. MOTION-BASE SIMULATOR STUDY OF CONTROL OF AN EXTERNALLY BLOWN FLAP STOL TRANSPORT AIRCRAFT AFTER FAILURE OF AN OUTBOARD ENGINE DURING LANDING APPROACH. NASA TN-D-8026, 1975.

* ABSTRACT *

A MOTION SIMULATOR STUDY OF THE PROBLEMS OF RECOVERY AND LANDING OF A STOL AIRCRAFT AFTER FAILURE OF AN OUTBOARD ENGINE DURING FINAL APPROACH WAS MADE. THE APPROACHES WERE AT 75 KNOTS ALONG A SIX-DEGREE GLIDESLOPE. THE ENGINE WAS FAILED AT LOW ALTITUDE AND THE OPTION TO OVERSHOOT WAS NOT ALLOWED. THE AIRCRAFT HAS FOUR HIGH-BYPASS-RATIO FAN-JET ENGINES EXHAUSTING AGAINST LARGE TRIPLE-SLOTTED WING FLAPS TO PRODUCE ADDITIONAL LIFT. IT WAS SIMULATED USING EACH OF THREE CONTROL SYSTEMS. A VISUAL SYSTEM SIMULATING A STOL AIRPORT WAS USED DURING PART OF THE STUDY. ALSO A SIMPLE HEAD-UP DISPLAY, SUPERIMPOSED ON THE AIRPORT LANDING SCENE, WAS USED BY THE PILOTS TO MAKE SOME OF THE RECOVERIES FOLLOWING AN ENGINE FAILURE. THE RESULTS INDICATED THAT THE VARIATION IN VISUAL CUES AND / OR MOTION CUES HAD LITTLE EFFECT ON THE OUTCOME OF A RECOVERY, BUT THEY DID HAVE SOME EFFECT ON THE PILOT'S RESPONSE AND CONTROL PATTERNS.

MILLER, D.P., AND VINGE, E.W. FIXED-BASE FLIGHT SIMULATOR STUDIES OF VTOL AIRCRAFT HANDLING QUALITIES IN HOVERING AND LOW-SPEED FLIGHT, TECHNICAL REPORT AFRDL-TR-67-152, AIR FORCE FLIGHT DYNAMICS LABORATORY, AIR FORCE SYSTEMS COMMAND, WRIGHT PATTERSON AFB, OHIO, JANUARY 1968.

* ABSTRACT *

A SYSTEMATIC INVESTIGATION OF VTOL LONGITUDINAL AND LATERAL HANDLING QUALITIES IN HOVERING AND LOW-SPEED FLIGHT WAS CONDUCTED IN A FIXED-BASE SIMULATOR. THE EFFECTS OF RATE DAMPING AND ATTITUDE STABILITY AUGMENTATION ON HANDLING QUALITIES FOR A RANGE OF SPEED-STABILITY AND DRAG PARAMETERS, TURBULENCE LEVELS, AND SEVERAL OTHER FACTORS WERE STUDIED. PILOTS SELECTED OPTIMUM CONTROL SENSITIVITY, PREPARED WRITTEN COMMENTS AND ASSIGNED PILOT OPINION RATINGS FOR EACH CONFIGURATION. THE RESULTS FOR MINIMUM SATISFACTORY HANDLING QUALITIES ARE CORRELATED WITH THE AIRCRAFT AND STABILITY AUGMENTATION PARAMETERS AND COMPARED WITH EXISTING AND SUGGESTED REQUIREMENTS FOR VTOL HANDLING QUALITIES. SUGGESTED CRITERIA FOR AIRCRAFT DYNAMIC CHARACTERISTICS AND MINIMUM RESPONSE TO CONTROL INPUTS THAT ARE BASED ON THE FLIGHT SIMULATOR DATA ARE PRESENTED. ROOT-MEAN-SQUARE PERFORMANCE DATA FOR A PRECISION HOVERING TASK WERE OBTAINED FOR A RANGE OF AIRCRAFT, STABILITY AUGMENTATION AND TURBULENCE LEVEL PARAMETERS. PILOT MODEL ADAPTED PARAMETERS FOR A MULTILOOP REPRESENTATION OF THE HOVERING TASK WERE COMPUTED FROM THESE RMS PERFORMANCE DATA AND CORRELATED WITH PILOT OPINION.

RESULTS SHOW THAT THE STABILITY AUGMENTATION AND OPTIMUM CONTROL SENSITIVITY REQUIREMENTS FOR SATISFACTORY HANDLING QUALITIES ARE DEPENDENT ON THE GUST SENSITIVITY OF THE AIRCRAFT. THE GENERALIZED RESULTS SHOW LITTLE CORRELATION WITH EXISTING OR SUGGESTED CRITERIA. INSTEAD THEY INDICATE THAT THE AIRCRAFT SPEED-STABILITY PARAMETERS MUST BE CONSIDERED IN THE DEVELOPMENT OF HANDLING QUALITIES SPECIFICATIONS. THE RMS HOVERING PERFORMANCE WAS DEPENDENT PRIMARILY ON POSITION-LOOP DISTURBANCES. CHANGES IN PITCH-LOOP DYNAMICS AND DISTURBANCE LEVEL HAD LITTLE EFFECT ON HOVERING PERFORMANCE EVEN WHEN THEY RESULTED IN LARGE CHANGES IN PILOT OPINION RATING. RESULTS OF THE STUDIES OF PILOT MODEL ADAPTED PARAMETERS SHOW THAT PILOT OPINION CORRELATES WELL WITH A COMBINATION OF ADAPTED LEAD AND AIRCRAFT GUST SENSITIVITY.

MILLER, F.E. B-58 MOTION STUDY. FINAL REPORT. ENGINEERING PSYCHOLOGY DEPARTMENT, LINK DIVISION, CONTRACT AF 33(600) 39037, APRIL 11, 1960.

* ABSTRACT *

AN EXPERIMENT WAS CONDUCTED TO OBTAIN INFORMATION RELEVANT TO THE PITCH MOTION SYSTEM OF THE B-58 SIMULATOR. PHASE I WAS CONCERNED WITH ESTIMATES OF PITCH ANGLES VARYING BETWEEN 5 DEGREES BELOW LEVEL AND 15 DEGREES ABOVE LEVEL WITHOUT VISUAL CUES. THREE METHODS OF ESTIMATION WERE USED UNDER VARIOUS CONDITIONS OF RATE AND DIRECTION OF APPROACH TO THE ANGLES. THE METHODS OF ESTIMATION WERE 1) ADJUSTING A BAR TO CORRESPOND WITH THE HORIZON, 2) ADJUSTING A FLAT BAR TO LEVEL, AND 3) VERBALLY ESTIMATING PITCH ANGLE. ON THE AVERAGE, THE ANGLES

WERE UNDERESTIMATED BY 2.3 DEGREES, 1.2 DEGREES, AND 2.6 DEGREES RESPECTIVELY. THE STANDARD DEVIATIONS OF ALL JUDGEMENTS AROUND THESE VALUES WERE 5.36 DEGREES, 6.62 DEGREES, AND 5.81 DEGREES RESPECTIVELY. STATISTICALLY SIGNIFICANT DIFFERENCES IN BOTH CONSTANT AND VARIABLE ERRORS RESULTED FROM DIFFERENCES AMONG THE ANGLES JUDGED AND FROM INDIVIDUAL DIFFERENCES AMONG THE SUBJECTS MAKING THE JUDGEMENTS. PHASE II WAS CONCERNED WITH JUDGMENTS OF THE SIMILARITY OF VARIOUS FEASIBLE SIMULATOR MOTIONS TO A STANDARD MOTION, BASED UPON B-58 FLIGHT CHARACTERISTICS. THE PROBLEM WAS TO SIMULATE REALISTICALLY PITCH ROTATION AROUND CENTER OF GRAVITY APPROXIMATELY 30 FEET BEHIND THE PILOT. THE MAJOR DIFFERENCE BETWEEN THE STANDARD MOTION AND THE TEST MOTION WAS THE AMOUNT OF VERTICAL MOVEMENT ASSOCIATED WITH PITCH ROTATION. OF THE MOTIONS WHICH WOULD BE FEASIBLE IN A SIMULATOR, ONE RESEMBLED THE STANDARD MOTION TO A SIGNIFICANTLY GREATER DEGREE THAN ANY OF THE OTHERS.

 MILLER, E.G., II AND GRAYBIEL, A. PERCEPTION OF THE UPRIGHT AND SUSCEPTIBILITY TO MOTION SICKNESS AS FUNCTIONS OF ANGLE OF TILT AND ANGULAR VELOCITY IN OFF-VERTICAL ROTATION. FIFTH SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE EXPLORATION, HELD AT THE NAVY AEROSPACE MEDICAL RESEARCH LAB., PENSACOLA, FL. AUG 19-21, 1970. PUBLISHED AS NASA SP-314, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., D.C., 1973.

* ABSTRACT *

MOTION SICKNESS SUSCEPTIBILITY OF FOUR NORMAL SUBJECTS WAS MEASURED IN TERMS OF DURATION OF EXPOSURE NECESSARY TO EVOKE MODERATE MALAISE (MIIA) AS A FUNCTION OF VELOCITY (2.5 TO 45 RPM) IN A CHAIR ROTATED ABOUT A CENTRAL AXIS TILTED 10 DEGREES WITH RESPECT TO GRAVITATIONAL UPRIGHT. THE SUBJECTS HAD LITTLE OR NO SUSCEPTIBILITY TO THIS TYPE OF ROTATION AT 2.5 AND 5.0 RPM, BUT WITH FURTHER INCREASES IN RATE, THE MIIA ENDPOINT WAS ALWAYS REACHED AND WITH EVER SHORTER TEST DURATIONS. MINIMAL PROVOCATIVE PERIODS FOR ALL SUBJECTS WERE FOUND AT 15 OR 20 RPM. HIGHER ROTATIONAL RATES DRAMATICALLY REVERSED THE VESTIBULAR STRESSOR EFFECT, AND THE SUBJECTS AS A GROUP TENDED TO REACH A PLATEAU OF RELATIVELY LOW SUSCEPTIBILITY AT 40 AND 45 RPM. AT THESE HIGHER VELOCITIES, FURTHERMORE, THE SUBJECTS ESSENTIALLY LOST THEIR SENSATION OF BEING TILTED OFF VERTICAL. IN THE SECOND HALF OF THE STUDY, THE EFFECT OF TILT ANGLE WAS VARIED WHILE THE ROTATION RATE WAS MAINTAINED AT A CONSTANT 17.5 RPM. TWO SUBJECTS WERE COMPLETELY RESISTANT TO SYMPTOMS OF MOTION SICKNESS WHEN ROTATED AT 2.5 DEGREES OFF VERTICAL; WITH GREATER OFF-VERTICAL ANGLES, THE SUSCEPTIBILITY OF ALL SUBJECTS INCREASED SHARPLY AT FIRST, THEN TAPERED OFF IN A MANNER REFLECTING A RECHNERIAN FUNCTION. THE MARKED CHANGES IN THESE MEASURED RESPONSES WERE ATTRIBUTED PRIMARILY TO THE MACULAR ORGANS BEING UNNATURALLY STIMULATED BY OFF VERTICAL ROTATION.

 MILLER, G.K.JR. 'A MOTION-CONSTRAINT LOGIC FOR MOVING-BASE SIMULATORS BASED ON VARIABLE FILTER PARAMETERS'. NASA LANGLEY RESEARCH CENTER FOR NASA WASHINGTON. NASA TECHNICAL NOTE, TN-D-7777, DECEMBER 1974.

* ABSTRACT *

A MOTION-CONSTRAINT LOGIC FOR MOVING-BASE SIMULATORS HAS BEEN DEVELOPED THAT IS A MODIFICATION TO THE LINEAR SECOND-ORDER FILTERS GENERALLY EMPLOYED IN CONVENTIONAL CONSTRAINTS. IN THE MODIFIED CONSTRAINT LOGIC THE FILTER PARAMETERS ARE NOT CONSTANT BUT VARY WITH THE INSTANTANEOUS MOTION BASE POSITION TO INCREASE THE CONSTRAINT AS THE SYSTEM APPROACHES THE POSITIONAL LIMITS. WITH THE MODIFIED CONSTRAINT LOGIC, ACCELERATIONS LARGER THAN ORIGINALLY EXPECTED ARE LIMITED WHILE CONVENTIONAL LINEAR FILTERS WOULD RESULT IN AUTOMATIC SHUTDOWN OF THE MOTION-BASE. IN ADDITION, THE MODIFIED WASHOUT LOGIC HAS FREQUENCY RESPONSE CHARACTERISTICS THAT ARE AN IMPROVEMENT FOR LOW FREQUENCY PILOT'S INPUTS. DURING SIMULATED LANDING APPROACHES OF AN EXTERNALLY BLOWN FLAP SHORT TAKE OFF AND LANDING (STOL) TRANSPORT USING DECOUPLED LONGITUDINAL CONTROLS, THE PILOTS WERE UNABLE TO DETECT MUCH DIFFERENCE BETWEEN THE MODIFIED CONSTRAINT LOGIC AND THE LOGIC BASED ON LINEAR FILTERS WITH BRAKING.

 MILLER, G.K.JR., AND DEAL, P.L. 'MOVING-BASE VISUAL SIMULATION STUDY OF DECOUPLED CONTROLS DURING APPROACH AND LANDING OF A STOL TRANSPORT AIRCRAFT'. NASA LANGLEY RESEARCH CENTER TECHNICAL NOTE TN-D-7790 JAN 1975.

* ABSTRACT *

A MOVING BASE VISUAL SIMULATION STUDY HAS BEEN CONDUCTED TO EVALUATE THE USE OF DECOUPLED CONTROLS DURING THE APPROACH AND LANDING OF AN EXTERNALLY BLOWN JET-FLAP STOL TRANSPORT. THE SIMULATION EMPLOYED ALL SIX RIGID-BODY DEGREES OF FREEDOM AND INCORPORATED AERODYNAMIC CHARACTERISTICS BASED ON WIND-TUNNEL DATA. THE FLIGHT INSTRUMENTATION INCLUDED A LOCALIZER AND A FLIGHT DIRECTOR. THE PRIMARY PILOTING TASK WAS TO CAPTURE AND TO MAINTAIN A TWO-SEGMENT GLIDE SLOPE BY USING THE FLIGHT DIRECTOR. A CLOSED CIRCUIT TELEVISION DISPLAY OF A STOL PORT PROVIDED VISUAL CUES DURING SIMULATIONS OF THE APPROACH AND LANDING. THE DECOUPLED LONGITUDINAL CONTROLS USED CONSTANT PREFILTER AND FEEDBACK GAINS TO PROVIDE STEADY-STATE DECOUPLING OF FLIGHT PATH ANGLE, PITCH ANGLE, AND FORWARD VELOCITY. THE PILOTS WERE ENTHUSIASTIC ABOUT THE DECOUPLED LONGITUDINAL CONTROLS AND BELIEVED THAT THE SIMULATOR MOTION WAS AN AID IN EVALUATING THE DECOUPLED CONTROLS, ALTHOUGH A MINIMUM TURBULENCE LEVEL WITH ROOT-MEAN-SQUARE GUST INTENSITY OF 0.3 M/SEC (1 FT/SEC) WAS REQUIRED TO MASK UNDESIRABLE CHARACTERISTICS OF THE MOVING BASE SIMULATOR.

 MILLER, G.D., JR., AND RILEY, D.R. THE EFFECT OF VISUAL-MOTION TIME DELAYS ON PILOT PERFORMANCE IN A PURSUIT TRACKING TASK. PROCEEDINGS OF THE AIAA VISUAL AND MOTION SIMULATION CONFERENCE, DAYTON, OHIO, APRIL 26-28, 1976.

* ABSTRACT *

A STUDY WAS MADE TO DETERMINE THE EFFECT OF VISUAL-MOTION TIME DELAYS ON PILOT PERFORMANCE OF A SIMULATED PURSUIT TRACKING TASK. THREE INTERRELATED MAJOR EFFECTS HAVE BEEN IDENTIFIED: TASK DIFFICULTY, MOTION CUES, AND TIME DELAYS. AS TASK DIFFICULTY, AS DETERMINED BY AIRPLANE HANDLING QUALITIES OR TARGET FREQUENCY, INCREASES, THE AMOUNT OF ACCEPTABLE TIME DELAY DECREASES. HOWEVER, WHEN RELATIVELY COMPLETE MOTION CUES ARE INCLUDED IN THE SIMULATION, THE PILOT CAN MAINTAIN HIS PERFORMANCE FOR CONSIDERABLY LONGER TIME DELAYS. IN ADDITION, THE NUMBER OF DEGREES OF FREEDOM OF MOTION EMPLOYED IS A SIGNIFICANT FACTOR.

 MILLER, G.D., JR., AND RILEY, D.R., THE EFFECT OF VISUAL-MOTION TIME DELAYS ON PILOT PERFORMANCE IN A SIMULATED PURSUIT TRACKING TASK, NASA LANGLEY RESEARCH CENTER, NASA TN D-8364 HAMP- TON, VIRGINIA FOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C., MARCH 1977. (ALSO IN PROCEEDINGS OF THE AIAA VISUAL AND MOTION SIMULATION CONFERENCE, DAYTON, OHIO, APRIL 26-28, 1976)

* ABSTRACT *

AN EXPERIMENTAL STUDY HAS BEEN MADE TO DETERMINE THE EFFECT ON PILOT PERFORMANCE OF TIME DELAYS IN THE VISUAL AND MOTION FEEDBACK LOOPS OF A SIMULATED PURSUIT TRACKING TASK. THREE MAJOR INTERRELATED FACTORS WERE IDENTIFIED: TASK DIFFICULTY EITHER IN THE FORM OF AIRPLANE HANDLING QUALITIES OR TARGET FREQUENCY, THE AMOUNT AND TYPE OF MOTION CUES, AND TIME DELAY ITSELF. IN GENERAL, THE GREATER THE TASK DIFFICULTY, THE SMALLER THE TIME DELAY THAT COULD EXIST WITHOUT DEGRADING PILOT PERFORMANCE. CONVERSELY, THE GREATER THE MOTION FIDELITY, THE GREATER THE TIME DELAY THAT COULD BE TOLERATED. THE EFFECT OF MOTION WAS, HOWEVER, PILOT DEPENDENT.

 MILLER, G.D. AND GOODSON, J.E. NOTE CONCERNING MOTION SICKNESS IN THE 2-FH-2 HSVER TRAINER. PENSACOLA, FLA. U.S. NAVAL SCHOOL OF AVIATION MEDICINE, 1958 (BUREAU OF MEDICINE AND SUR- GERY, PROJECT NM170111) (AD 204 234)

* ABSTRACT *

A REVIEW WAS MADE OF THE DEVELOPMENT OF DEVICE 2-FH-2, INCLUDING TWO EVALUATIONS. THESE EVALUATIONS POINTED WITH NO LITTLE CONCERN TO THE PROBLEM OF 'MOTION SICKNESS' EXPERIENCED IN THE SIMULATOR.

THE WRITERS FEEL THAT THE HYPOTHESES OFFERED BY OTHERS TO THE EFFECT THAT THESE SYMPTOMS WERE ELICITED BY THE CONFLICT BETWEEN VISUAL CUES OF MOTION AND STATIC PHYSIOLOGICAL CUES IS FALSE. THE PROBLEM SEEMS TO LIE IN ONE OR A COMBINATION OF SEVERAL MODES OF DISTORTION: THERE EXIST BOTH STATIC AND DYNAMIC DISTORTIONS IN THE PROJECTED SCENERY; THERE ARE ERRORS IN THE PERCEIVED DIRECTIONAL CHANGES OF MOTION; AND THERE ARE DYNAMIC ERRORS IN THE PERCEIVED ANGULAR RATE OF MOTION. THESE DISTORTIONS ARE POINTED OUT HEREIN AND SUGGESTIONS ARE MADE AS TO HOW THEY MIGHT BE ALLEVIATED.

MILLER, J.W. AND GORDSON, J.E. MOTION SICKNESS IN A HELICOPTER SIMULATOR. 'AEROSPACE MEDICINE', 1960, 31, 204-212.

* ABSTRACT *

SIMULATION OF OPERATIONAL AIRCRAFT HAS BECOME AN INCREASINGLY IMPORTANT ASPECT OF FLIGHT TRAINING FOR REASONS OF ECONOMY, SAFETY, EXPEDIENCY. IN 1956, A HELICOPTER SIMULATOR WAS DESIGNED AND INSTALLED AS A TRAINING DEVICE IN PENSACOLA, FLA., FOR THE DUAL PURPOSE OF EVALUATING A POINT SOURCE SYSTEM OF OPTICAL PROJECTION AND AS A POSSIBLE MEANS OF FACILITATING THE TRAINING OF HELICOPTER PILOTS. DURING THE INITIAL STAGES OF UTILIZATION A NUMBER OF PROBLEMS AROSE CONCERNING THE DESIRABILITY OF EMPLOYING THIS DEVICE AS A TRAINING INSTRUMENT. ONE OF THE MOST SERIOUS DIFFICULTIES ENCOUNTERED WAS THAT OF SO CALLED MOTION SICKNESS IN A COCKPIT THAT DID NOT ACTUALLY MOVE. THE PROBLEM BECAME SO SERIOUS THAT IT WAS ONE OF THE CHIEF REASONS FOR DISCONTINUING THE USE OF THE SIMULATOR. THE AUTHORS POSTULATED THE POSSIBILITY THAT THE BASIC PROBLEM UNDERLYING THE MOTION SICKNESS REPORTED INVOLVED CONFLICTING VISUAL CUES RATHER THAN A CONFLICT BETWEEN VISUAL AND PROPRIOCEPTIVE CUES.

MILLER, N. (ED.) 'PSYCHOLOGICAL RESEARCH ON PILOT TRAINING'. ARMY AIR FORCE AVIATION PSYCHOLOGY PROGRAM RESEARCH REPORT NO. 2. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 1947.

* ABSTRACT *

THE PURPOSE OF THIS REPORT IS TO PROVIDE A RECORD OF THE RESEARCH ON PILOT TRAINING CONDUCTED BY AVIATION PSYCHOLOGISTS UNDER THE OFFICE OF THE SURGEON IN THE AAF TRAINING COMMAND. MOST OF THE RESEARCH SUMMARIZED IN THIS REPORT WAS CONDUCTED BY PSYCHOLOGICAL RESEARCH PROJECT (PILOT), AN ORGANIZATION WHICH

WAS ESTABLISHED AND MADE RESPONSIBLE FOR PSYCHOLOGICAL RESEARCH ON PILOT TRAINING ON 1 FEBRUARY, 1944.

THE FINAL CHAPTER (NO. 15) IS A SUMMARY PRESENTED FOR THE BENEFIT OF THOSE READERS WHO ARE MORE INTERESTED IN AN INTEGRATED PICTURE OF THE MAIN RESULTS THAN IN THE TECHNICAL DETAILS OF THE SEPARATE STUDIES.

MILLER, R.B. 'PSYCHOLOGICAL CONSIDERATIONS IN THE DESIGN OF TRAINING EQUIPMENT'. WRIGHT AIR DEVELOPMENT CENTER, OHIO WADC-TR-54-563, DECEMBER 1954.

* ABSTRACT *

A TRAINING DEVICE IS A MACHINE WHOSE PURPOSE IS TO TEACH JOB SKILLS WHICH WILL TRANSFER TO OPERATIONAL SITUATIONS. AS SUCH, THE HUMAN FACTORS INVOLVED IN EFFICIENT LEARNING AND TRANSFER OF TRAINING ARE CONSIDERATIONS ESSENTIAL TO ECONOMY AND TRAINING VALUE OF TRAINER DESIGN. THE REPORT PRESENTS A NUMBER OF CONSIDERATIONS AND RECOMMENDATIONS FOR TRAINER DESIGN UNDER THE FOLLOWING TOPICS: I. SOME PRINCIPLE CONCEPTS IN LEARNING AND TRANSFER OF LEARNING; II. PROBLEMS OF PHYSICAL SIMULATION; III. STAGE OF LEARNING AND DEGREE OF PHYSICAL SIMULATION; IV. KNOWLEDGE OF RESULTS AND SCORING; V. RECORDING PROCEDURES; VI. PROFICIENCY MEASUREMENT; VII. THE DESIGN OF INSTRUCTOR'S STATION; VIII. THE TRAINER AS A DEMONSTRATOR OF PRINCIPLES; IX. OUTLINE OF STEPS IN DESIGNING A TRAINING DEVICE.

THIS REPORT IS ESSENTIALLY A DIGEST OF PREVIOUSLY PUBLISHED MATERIAL BY THE AUTHOR AND DR. ALAN D. SWAIN. IT HAS BEEN ADAPTED FOR PERSONS WHO MAY NOT HAVE A PROFESSIONAL BACKGROUND IN PSYCHOLOGY. THE REPORT IS INTENDED FOR THOSE WHO PARTICIPATE IN FRAMING THE REQUIREMENTS FOR TRAINING DEVICES, DESIGNING THEM AND, IN LESSER DEGREE, FOR THOSE WHO USE THEM IN TRAINING.

MILLIGAN, J.R. SIMULATION OF LOW ALTITUDE HIGH SPEED MISSION PERFORMANCE. 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE PAPER, 70-343, CAPE CANAVERAL, FL, MAR 16-18, 1970.

* ABSTRACT *

A SERIES OF SIMULATION TESTS WERE CONDUCTED TO TEST AND EVALUATE FIVE PROTOTYPE AIRCRAFT FLIGHT DISPLAYS. THREE OF THE DISPLAYS WERE DESIGNED PRIMARILY FOR TERRAIN FOLLOWING AND TWO FOR NAVIGATION. THE TESTS WERE MADE IN SIMULATED FLIGHT FOR REASONS OF SAFETY AND ECONOMY AND TO ACHIEVE PRECISE CONTROL OF RELEVANT MECHANICAL AND ENVIRONMENTAL PARAMETERS. A FOUR DEGREE OF FREEDOM DYNAMIC FLIGHT SIMULATOR (DFS) WAS USED IN THE STUDY. THE DFS WAS AN ANALOG OF A REAL AIRCRAFT IN THAT IT MOVED

VERTICALLY, Laterally, AND PITCHED AND ROLLED WHEN THE CONTROL STICK IN THE COCKPIT WAS MOVED. A TELEVISED PICTURE OF THE OUT-OF-THE-COCKPIT VIEW WAS A REAR-PROJECTED ONTO A TRANSLUCENT SCREEN IN FRONT OF THE CFS. RESULTS SHOWED THAT A HEAD-UP DISPLAY OF TERRAIN-FOLLOWING INFORMATION WAS GENERALLY SUPERIOR TO AN IN-COCKPIT DISPLAY OF THE SAME INFORMATION, AND THAT A NAVIGATION DISPLAY BASED ON INPUTS FROM AN INERTIAL GUIDANCE SYSTEM WAS SUPERIOR TO CONVENTIONAL DEAD RECKONING NAVIGATION. ALTHOUGH SOME OF THE BASIC CONCEPTS WERE EXCELLENT, PILOT REACTION INDICATED ALL DISPLAYS REQUIRED FURTHER DEVELOPMENT PRIOR TO OPERATIONAL USE. (AUTHOR)

MILLS, C.E.
TECHNIQUES FOR IMPROVING THE QUALITY OF MOTION REPRODUCTION IN TRAINING BASE, PILOTED, FLIGHT SIMULATORS. AIAA PAPER NO. 67-252. AIAA-FLIGHT TEST, SIMULATION AND SUPPORT CONFERENCE, CROCHAM BEACH FLORIDA, FEBRUARY 6-8 1967.

* ABSTRACT *

MOTION REPRODUCTION IS EXAMINED FROM THE VIEWPOINT OF THE DESIGN AND OPERATION OF THE SIMULATOR MOTION CONTROL SYSTEMS. QUALITY IS CHOSEN IN THE CONTEXT OF DYNAMIC FIDELITY, THE ELIMINATION OF SPURIOUS SMALL ABRUPT DISCONTINUITIES IN THE ACCELERATION RESPONSE, AND THE ATTENUATION OF UNWANTED DYNAMIC MODES WHICH REFLECT CHARACTERISTICS OF THE SIMULATOR STRUCTURE. THE TECHNIQUES DISCUSSED HAVE BEEN RECENTLY APPLIED AND EXPERIMENTAL EVALUATIONS ARE PRESENTED. MOTION SERVICES WHICH HAVE BEEN SYNTHESIZED TO ACCEPT VOLTAGE COMMANDS CONSTRUCTED FROM HIGHER MOTION DERIVATIVES ARE SHOWN TO OFFER SIGNIFICANT IMPROVEMENTS IN THE FIDELITY OF MOTION REPRODUCTION. THE TECHNIQUE RELIES ON THE AVAILABILITY OF HIGHER DERIVATIVE COMMAND SIGNALS, AS VOLTAGE ANALOGS IN THE TYPICAL ANALOG SIMULATION OF THE AIRCRAFT MOTION EQUATIONS. A FEEDBACK TECHNIQUE IS DESCRIBED WHICH ALLEVIATES THE PROBLEM OF CONTROLLING SIMULATOR MOTIONS WHERE CONTROL FORCES MUST BE TRANSMITTED TO THE COCKPIT OVER A RELATIVELY COMPLIANT STRUCTURE. THE TECHNIQUE IS IMPLEMENTED BY BRINGING THE COUPLING STRUCTURE INSIDE AN ACCELERATION FEEDBACK CONTROL LOOP. APPLIED TO THE CONTROL OF VERTICAL AND LATERAL COCKPIT TRANSLATIONS, THE TECHNIQUE REMOVES THE MOST TROUBLESOME EFFECTS OF SIMULATOR STRUCTURAL DYNAMICS FROM THE CLOSED LOOP MOTION RESPONSE.

VAN DE VESDICK, G.A.J. NON-GAUSSIAN STRUCTURE OF THE SIMULATED TURBULENT ENVIRONMENT IN PILOTED FLIGHT SIMULATION
Delft University of Technology
Department of Aerospace Engineering MEMORANDUM M-304 PRESENTED AT THE AGARD/FME SPECIALISTS MEETING ON: PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, 24-27 APRIL 1978, BRUSSELS, BELGIUM

* ABSTRACT *

AFTER A DESCRIPTION OF THE GENERAL NON-GAUSSIAN CHARACTERISTICS OF ACTUAL ATMOSPHERIC TURBULENCE AS OBSERVED IN THE ATMOSPHERE, A NON-GAUSSIAN TURBULENCE SIMULATION MODEL HAS BEEN DESCRIBED. THE NON-GAUSSIAN CHARACTERISTICS HAVE BEEN CLASSIFIED AS PATCHINESS AND INTERMITTENCY, BOTH DEPENDENT ON HIGHER ORDER STATISTICS. THESE NON-GAUSSIAN CHARACTERISTICS HAVE BEEN MATHEMATICALLY ELABORATED AND DESCRIBED.

THE EFFECTS OF PATCHINESS ON PILOT'S BEHAVIOUR, USING PHYSIOLOGICAL PARAMETERS HAVE BEEN EVALUATED IN A SMALL SIMULATOR EXPERIMENT.

MORRIS, E.O., J.M. LENTZ, F.E. GLEDTRY, JR.
NAUSEOGENIC VISUAL-VESTIBULAR INTERACTION IN A VISUAL SEARCH TASK. NAMRL-1234. PENSACOLA, FL: NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY, 30 MARCH 1977.

* ABSTRACT *

THIS STUDY DESCRIBES THE DEVELOPMENT OF A VISUAL-VESTIBULAR INTERACTION (VVI) TEST WHICH MAY BE USEFUL IN PREDICTING MOTION SICKNESS SUSCEPTIBILITY IN WORKING SITUATIONS ABOARD SHIP, AIRCRAFT, AND OTHER MOVING VEHICLES.

THE NAUSEOGENIC ASPECT OF VISUAL SUPPRESSION OF THE VESTIBULO-OCCULAR NYSTAGMUS REFLEX WAS EVALUATED IN THREE EXPERIMENTS. IN APPROXIMATELY 5 PERCENT OF THE SUBJECTS TESTED, MOTION SICKNESS SYMPTOMS, INCLUDING VOMITING, DEVELOPED. THE ESTABLISHMENT OF INDIVIDUAL SENSITIVITIES TO THIS FORM OF MOTION SICKNESS IS NOTEWORTHY, NOT ONLY BECAUSE OF THE SIMILARITY OF THE VISUAL TASK TO APPLIED PERFORMANCE, BUT IT ALSO PROVIDES A BASIS FOR INVESTIGATING THE TYPES OF DISPLAYS AND VISUAL LOADS ENCOUNTERED IN MOVING VEHICLES.

MORRIS, E. AND MATTHEWS, N.O. NEW VISUAL AND MOTION TECHNIQUES IN MILITARY FLIGHT SIMULATION. PROCEEDINGS OF ROYAL AERONAUTICAL SOCIETY SYMPOSIUM 'THEORY AND PRACTICE IN FLIGHT SIMULATION', LONDON, ENGLAND, APRIL 1976.

* ABSTRACT *

THE AUTHORS ILLUSTRATE THE DIFFERENCES IN REQUIREMENTS BETWEEN CIVIL AND MILITARY SIMULATOR TRAINING. SOME RECENT DEVELOPMENTS IN MOTION AND VISUAL SYSTEMS ARE DESCRIBED, AND THEIR VALIDITY AND APPLICATION TO MILITARY TRAINING ARE DISCUSSED. MILITARY TRAINING IS NECESSARILY MORE COMPLEX AND DEMANDING THAN ITS CIVIL COUNTERPART. WHILE THE CIVIL PILOT AVOIDS EXCESSIVE ACCELERATIONS AND VIOLENT MANEUVERS CLOSE TO THE GROUND, THIS IS THE MILITARY PILOT'S STOCK IN TRADE. MILITARY SIMULATORS MUST,

THEREFORE, PROVIDE REALISTIC ACCELERATIONS IN ORDER TO ACCLIMATE THE PILOT, AND TO GIVE HIM CONFIRMATORY CUES TO SUBSTANTIATE HIS CONTROL INPUTS. A GREATER VISUAL CAPABILITY MUST BE PROVIDED FOR EFFECTIVE TRAINING IN LAHS FLIGHT, TARGET ACQUISITION AND ATTACK SIMULATION. FOR THESE, AN ALL-ROUND FIELD OF VIEW IS ESSENTIAL.

MARRIS, W.B., MCCORMICK, R.L. AND SINACORI, J.B. A MOVING BASE SIMULATION STUDY OF AN ALL MECHANICAL CONTROL SYSTEM FOR VTOL AIRCRAFT. AIAA SIMULATION FOR AEROSPACE FLIGHT CONFERENCE, COLUMBUS, OH., AUG. 26-28, 1963.

* ABSTRACT *

A SIMULATION STUDY HAS BEEN CONDUCTED BY NORTHROP NORAIR, A DIVISION OF NORTHROP CORPORATION, UNDER NAVY CONTRACT TO DETERMINE THE OPTIMUM SHAPING OF CONTROL POWER WHICH PROVIDES HANDLING QUALITIES THAT REQUIRE LITTLE EFFORT ON THE PART OF THE PILOT TO MAINTAIN GOOD CONTROL. THIS STUDY WAS ACCOMPLISHED DURING THE SUMMER AND FALL OF 1962 USING A TWO-AXIS MOVING BASE SIMULATOR. SIX DEGREES OF FREEDOM WERE SIMULATED AND DISPLAYED WHILE MOTION WAS IMPARTED ABOUT THE PITCH AND ROLL AXES. THE COCKPIT WAS ENCLOSED AND ALL EVALUATIONS WERE MADE SOLELY BY REFERENCE TO INSTRUMENTS. THE PILOTS WERE REQUIRED TO CONTROL MOTION ABOUT ALL AXES WHILE EVALUATING A SINGLE MODE. AFTER THE MOST ACCEPTABLE CONTROL PARAMETERS WERE DETERMINED, THEY WERE THEN DESIGNED INTO HARDWARE WHICH WAS THEN INSTALLED IN THE SIMULATOR AND, IN TURN, EVALUATED.

MANNING, G.H. AND GERHARD, J.W. MAN'S SENSES AS INFORMATIONAL CHANNELS. APPLIED PHYSICS LAB. REPORT CM-936, JOHNS HOPKINS UNIVERSITY, SILVER SPRING, MARYLAND, MAY, 1958. PP VI + 65. (ALSO PUBLISHED AS PAPER 5 IN SELECTED PAPERS ON HUMAN FACTORS IN THE DESIGN AND USE OF CONTROL SYSTEMS, EDITED BY H. WALLACE SINGAR, COVER PUBLICATIONS, INC.: NEW YORK, 1961.)

* ABSTRACT *

THIS REVIEW BRINGS TOGETHER MANY OF THE FACTS THAT ARE KNOWN ABOUT THE SENSES. ONE SECTION IS CONCERNED WITH THE EFFECT OF LABYRINTHINE STIMULATIONS ON VISUAL PROCESSES. A DIRECT COMPARISON IS MADE OF THE LIMITS, THE RELATIVE STIMULUS MAGNITUDES THAT MAY BE TOLERATED, AND THE SENSITIVITIES OF THE VARIOUS SENSES. INTERACTION AMONG SIMULTANEOUSLY STIMULATED SENSORY CHANNELS HAS ALSO BEEN INCLUDED.

MATZELL, M.M. AND WHITE, D.C. 'BEHAVIORAL EFFECTS OF WHOLE BODY VIBRATION'. 'AVIATION MEDICINE', OCTOBER 1958.

* ABSTRACT *

A STUDY WAS MADE OF THE EFFECT OF WHOLE BODY VIBRATION ON THE ABILITY OF HUMANS TO READ THE DIGITS OF AN AIRCRAFT MILEAGE INDICATOR AND THEIR ABILITY TO DO A TRACKING TASK WHICH SIMULATED THE CONTROL OF AN AIRCRAFT. VERTICAL SINUSOIDAL VIBRATION OF FREQUENCIES RANGING BETWEEN 0 AND 50 CPS WITH AMPLITUDES OF 0.05, 0.1 AND 0.16- INCH DOUBLE AMPLITUDE WERE USED. IT IS CONCLUDED THAT INCREASING THE FREQUENCY OF VIBRATION ABOVE 8 CPS HAS AN INCREASINGLY DETRIMENTAL EFFECT ON VISUAL PERFORMANCE. THIS EFFECT REACHES A MAXIMUM BETWEEN 40 AND 50 CPS. THE INCREASE OF AMPLITUDE OF VIBRATION FROM 0.05 TO 0.1 INCH DOUBLE AMPLITUDE HAS NO EFFECT UPON VISUAL PERFORMANCE. A CASE WAS MADE FOR USING FREQUENCY AND AMPLITUDE RATHER THAN G AS VIBRATION CO-ORDINATES. IT IS CONCLUDED THAT VIBRATION, WITHIN THE LIMITS OF THE EXPERIMENT HAS LITTLE EFFECT UPON TRACKING ABILITY.

MUCKLER, F.A., NYGAARD, J.E., BIKELLY, B.I., AND WILLIAMS, A.C. JR. PSYCHOLOGICAL VARIABLES IN THE DESIGN OF FLIGHT SIMULATORS FOR TRAINING. AVIATION PSYCHOLOGY LABORATORY, UNIVERSITY OF ILLINOIS FOR AERO MEDICAL LABORATORY WRIGHT AIR DEVELOPMENT CENTER, WRIGHT-PATTERSON AFB, OHIO WADC TECHNICAL REPORT 56-369, JANUARY 1959.

* ABSTRACT *

OVER THE PAST TEN YEARS, THE AIR FORCE HAS BECOME INCREASINGLY DEPENDENT UPON FLIGHT SIMULATORS AND TRAINERS AS PART OF ALMOST ALL FLIGHT TRAINING PROGRAMS. IN THE DESIGN, CONSTRUCTION, AND UTILIZATION OF THESE SYNTHETIC TRAINING DEVICES, TWO GENERAL PROBLEM AREAS HAVE BEEN FREQUENTLY CONTRASTED. THE FIRST OF THESE AREAS IS THE DEGREE OF FIDELITY OF PHYSICAL SIMULATION THAT MAY BE ACHIEVED BETWEEN THE FLIGHT TRAINING DEVICE AND THE OPERATIONAL AIRCRAFT. THIS PROBLEM HAS BEEN THE CONCERN OF SIMULATOR DESIGN ENGINEERS, AND IT HAS BEEN TERMED THE PROBLEM OF PHYSICAL SIMULATION. THE SECOND PROBLEM AREA IS BASED ON THE ULTIMATE CRITERION OF ANY SYNTHETIC TRAINING DEVICE: THE TRAINING VALUE THAT RESULTS FROM THE USE OF THE DEVICE. THIS IS FUNDAMENTALLY A PSYCHOLOGICAL PROBLEM OF TRANSFER OF TRAINING FROM THE DEVICE TO THE AIRCRAFT THAT INVOLVES THE PSYCHOLOGICAL SIMILARITY BETWEEN TRAINER AND AIRCRAFT TASKS. IT IS HERE TERMED THE PROBLEM OF PSYCHOLOGICAL SIMULATION.

A SURVEY OF MANY OF THE PROBLEMS THAT HAVE ARISEN IN THE CONTEXT OF PSYCHOLOGICAL SIMULATION IS INCLUDED. THE EXISTING TRAINING RESEARCH LITERATURE ON FLIGHT TRAINERS AND SIMULATORS IS EVALUATED, AND A NUMBER OF EXPERIMENTAL PROGRAMS ARE SUGGESTED. FURTHER, IN THE HISTORY OF THE DESIGN AND UTILIZATION OF FLIGHT TRAINING DEVICES, SEVERAL SPECIFIC PROBLEM AREAS HAVE CONTINUALLY APPEARED. THESE AREAS HAVE BEEN EXAMINED BRIEFLY, WITH PARTICULAR EMPHASIS ON POSSIBLE EMPIRICAL SOLUTIONS. IN ADDITION, MOTIVATIONAL, INSTRUCTIONAL, AND METHODOLOGICAL

VARIABLES ARE CONSIDERED. FINALLY, CONVENTIONAL THEORIES OF TRANSFER OF TRAINING ARE EVALUATED IN TERMS OF THEIR PREDICTIVE EFFICACY IN THE AREA OF FIDELITY OF PSYCHOLOGICAL SIMULATION.

MUCKLER, F.A., OBERMAYER, R.W., AND HANLON, W.H. TRANSFER OF TRAINING WITH SIMULATED AIRCRAFT DYNAMICS: I. VARIATIONS IN PERIOD AND DAMPING OF THE PHUGOID RESPONSE. AERONAUTICAL SYSTEMS DIV., AEROSPACE MEDICAL RESEARCH LABORATORIES, WRIGHT-PATTERSON AFB, OH, RPT. WADD TR 60-615 (I), DEC 1961.

* ABSTRACT *

THIS REPORT IS THE THIRD IN A SERIES OF EXPERIMENTS DEALING WITH TRANSFER OF TRAINING AS A FUNCTION OF SIMULATED AIRCRAFT LONGITUDINAL DYNAMICS. SUBJECTS PERFORMED SINGLE DIMENSION COMPENSATORY TRACKING WITH LONG PERIOD (PHUGOID) OSCILLATORY CONTROL SYSTEM DYNAMICS. TWO EXPERIMENTS ARE REPORTED DEALING WITH CHANGES IN COURSE COMPLEXITY AND AMPLITUDE OF THE EXPERIMENTAL STIMULUS FORCING FUNCTION. INCREASING COURSE COMPLEXITY WAS FOUND TO SUBSTANTIALLY AFFECT TRANSFER OF TRAINING, BUT NOT TRAINING PERFORMANCE. INCREASING COURSE AMPLITUDE MARKEDLY AFFECTED TRAINING PERFORMANCE, BUT NOT TRANSFER OF TRAINING. IN GENERAL, TRANSFER EFFECTS WERE GREATER FROM LESS DIFFICULT TO MORE DIFFICULT TASK CONDITIONS. THESE RESULTS ARE SUPERFICIALLY INCONSISTENT WITH PREVIOUSLY REPORTED STUDIES. HOWEVER, MANY OF THE PHENOMENA ARE DIRECTLY ATTRIBUTABLE TO THE PRESENCE OF COMPLEX SYSTEM DYNAMICS WHICH WERE ABSENT IN PRIOR STUDIES.

MUCKLER, F.A., OBERMAYER, R.W., HANLON, W.H. AND SERIO, F.P. TRANSFER OF TRAINING WITH SIMULATED AIRCRAFT DYNAMICS: III. VARIATIONS IN COURSE COMPLEXITY AND AMPLITUDE. AERONAUTICAL SYSTEMS DIV., AEROSPACE MEDICAL RESEARCH LABORATORIES, WRIGHT-PATTERSON AFB, OH, RPT. WADD TR 60-615 (III), DEC 1961.

* ABSTRACT *

THIS REPORT IS THE SECOND IN A SERIES DEALING WITH TRANSFER OF TRAINING AS A FUNCTION OF SIMULATED AIRCRAFT LONGITUDINAL DYNAMICS. SUBJECTS PERFORMED SINGLE DIMENSION COMPENSATORY TRACKING WITH LONG PERIOD (PHUGOID) OSCILLATORY CONTROL SYSTEM DYNAMICS. THREE EXPERIMENTS ARE REPORTED DEALING WITH VARIATIONS IN CONTROL GAIN. INCREASING CONTROL GAIN RESULTED IN EQUALLY HIGH TRAINING AND TRANSFER PERFORMANCE FOR ALL OSCILLATORY TRANSIENT CONDITIONS STUDIED, BUT AT A LOWER GAIN LEVEL, SIGNIFICANT DIFFERENCES WERE FOUND. IF RATE OF ONSET OF THE TRANSIENT CONDITIONS WERE NOT EQUATED BY ADJUSTING CONTROL GAIN, SIGNIFICANT NEGATIVE RELATIVE TRANSFER OF TRAINING WAS ELICITED. EQUALIZATION OF RATE OF ONSET, HOWEVER, SUBSTANTIALLY REDUCED TRAINING PERFORMANCE DIFFERENCES AND ELIMINATED NEGATIVE TRANSFER EFFECTS.

MUCKLER, F.A., OBERMAYER, R.W., HANLON, W.H. AND SERIO, F.P.
TRANSFER OF TRAINING WITH SIMULATED AIRCRAFT DYNAMICS: II.
VARIATIONS IN CONTROL GAIN AND PHUGOID CHARACTERISTICS. AERO.
NAUTICAL SYSTEMS DIV., AEROSPACE MEDICAL RESEARCH LABORATORIES,
WRIGHT-PATTERSON AFB, OH, RPT. WADD TR 60-615 (II), DEC. 1961.

* ABSTRACT *

THIS REPORT IS THE FIRST IN A SERIES OF EXPERIMENTS DEALING
WITH TRANSFER OF TRAINING AS A FUNCTION OF VARIATIONS IN
SIMULATED AIRCRAFT LONGITUDINAL DYNAMICS. SUBJECTS PERFORMED
SINGLE-DIMENSION COMPENSATORY TRACKING WITH AN APPARATUS USING
LONG-PERIOD OSCILLATORY TRANSIENTS (THE PHUGOID RESPONSE) AS
CONTROL SYSTEM DYNAMICS. TWO EXPERIMENTS ARE DISCUSSED:
(A) PERIOD AND DAMPING VARIATIONS OF THE PHUGOID RESPONSE, AND
(B) PILOT AND NON-PILOT PERFORMANCE WITH A VERY LONG PERIOD,
POORLY DAMPED TRANSIENT.

MUCKLER, F.A. AND OBERMAYER, R.W. CONTROL SYSTEM LAGS AND MAN-
MACHINE SYSTEM PERFORMANCE. NASA CONTRACTOR REPORT NASA CR-83.
JULY 1964.

* ABSTRACT *

THIS REVIEW EXAMINES THE MANUAL CONTROL SYSTEM LITERATURE ON THE
EFFECTS OF SYSTEM LAGS TO CLARIFY MAJOR CONCEPTUAL, ANALYTIC,
AND TERMINOLOGICAL PROBLEMS. FOUR CONTROL SYSTEM LAGS ARE
DEFINED: TRANSMISSION, EXPONENTIAL, SIGMOID, AND OSCILLATORY
TRANSIENT DELAYS. THE EFFECTS OF LAGS ON HUMAN PERFORMANCE ARE
ILLUSTRATED THROUGH STUDIES OF SINGLE CONTROL LAG VARIABLES.
HOWEVER, SINCE THE INTERACTION OF TASK VARIABLES MARKEDLY
INFLUENCES TRACKING PERFORMANCE LEVELS, AN ANALYSIS OF THE
CONTROL LAG LITERATURE IS CONDUCTED ACROSS THE FOLLOWING TASK
VARIABLES: SYSTEM INPUTS, INFORMATION SOURCES, OPERATOR
CONTROLS, CONTROLLED ELEMENT AND ENVIRONMENTAL VARIABLES.
ADDITIONALLY, THE RELATION BETWEEN CONTROL LAGS AND THE
PROCEDURAL VARIABLE OF TRANSFER OF TRAINING IS DISCUSSED.

MUDD, S. ASSESSMENT OF THE FIDELITY OF DYNAMIC FLIGHT-SIMULA-
TORS. HUMAN FACTORS 10: 351-358, 1968.

* ABSTRACT *

THE EVALUATION OF DYNAMIC FLIGHT SIMULATORS IS CONSIDERED FROM
THE STANDPOINT OF THE EFFICIENCY AND VALIDITY OF THE CURRENTLY
USED PILOT EVALUATIONS AND ASSESSMENT TECHNIQUES. A SET OF
REQUIREMENTS FOR AN IDEAL FIDELITY MEASUREMENT TECHNIQUE IS
PRESENTED, FOLLOWED BY A COMPARISON OF THE TWO GENERAL

APPROACHES TO FIDELITY MEASUREMENT, THE ANALYTIC AND THE EMPIRICAL, WITH REFERENCE TO THOSE REQUIREMENTS. A HYBRID METHOD WHICH INVOLVES THE USE OF PILOT PSYCHOMOTOR RESPONSES RATHER THAN VERBAL RESPONSES IS INTRODUCED. THIS TECHNIQUE RETAINS THE SUBJECTIVE CHARACTERISTIC OF RATING SCALES, BUT PROVIDES INFORMATION OF AN ANALYTIC NATURE THAT IS MORE AMENABLE TO ENGINEERING ANALYSIS. PROBLEMS INVOLVED IN THE DEVELOPMENT OF THE TECHNIQUE ARE CONSIDERED.

MULFERN, C.J. THE PHYSICAL AND FUNCTIONAL CHARACTERISTICS OF FLIGHT CONTROL SYSTEMS SIMULATORS. U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PA, REPORT NADC-ED-5913, 28 APRIL 1959.

* ABSTRACT *

THE PHYSICAL AND FUNCTIONAL CHARACTERISTICS OF FLIGHT CONTROL SYSTEM SIMULATORS CURRENTLY SERVING THE AIRCRAFT INDUSTRY WERE DETERMINED AND ARE DISCUSSED. SIMULATION METHODS AND TECHNIQUES ARE DISCUSSED BRIEFLY. FACTORS INFLUENCING THE DEGREE OF COMPLEXITY OF FLIGHT SIMULATORS ARE EXPLAINED. (AUTHOR)

W.F. MYLES, ET AL - VIBRATORY SIMULATOR MOTION SYSTEM
PATENT NO. 3,984,924
FILED JUNE 23, 1975 GRANTED OCT. 12, 1976

NO ABSTRACT

NADLER, A.B. VIBRATION. IN BURNS, N.M., CHAMBERS, R.M. AND HENDLER, E. (EDS.) UNUSUAL ENVIRONMENTS AND HUMAN BEHAVIOR. COLLIER-MACMILLAN LTD., LONDON, 1963.

* ABSTRACT *

THIS CHAPTER IS PRIMARILY CONCERNED WITH THE EFFECTS OF VIBRATORY FORCES UPON BIOLOGICAL SYSTEMS, PARTICULARLY THE HUMAN ORGANISM. EXPERIMENTAL STUDIES USING ANIMALS AND HUMANS ARE DESCRIBED. BEHAVIORAL EFFECTS OF WHOLE-BODY VIBRATION AND PROTECTION AGAINST VIBRATION ARE ALSO COVERED.

NADLER, G. THE MEASUREMENT OF THREE-DIMENSIONAL HUMAN MOTIONS. IN BENNETT, E., DEGAN, J. AND SPIEGEL, J. (EDS.) HUMAN FACTORS IN TECHNOLOGY. HUMAN FACTORS SOCIETY, MCGRAW-HILL, NEW YORK, 1963.

* ABSTRACT *

THIS REPORT DESCRIBES THE DESIGN AND USE OF A DEVICE DEVELOPED PRIMARILY FOR THE STUDY OF WORK METHODS, E.G., TIME AND MOTION STUDIES. MOTION IS MEASURABLE IN TERMS OF ACCELERATION, VELOCITY, DECELERATION, POSITION IN SPACE, TRUE DISTANCE TRAVELED, AND TIME. WHEN SUCH MEASUREMENTS ARE MADE FOR BODY MEMBERS, CERTAIN FACTORS HAVE TO BE CONSIDERED. THE MEASUREMENTS MUST BE THREE-DIMENSIONAL. ANY ATTACHMENTS TO THE BODY MEMBER STUDIED MUST BE SMALL AND LIGHT. ANY MEASUREMENT DEVICE DEVELOPED MUST BE USABLE UNDER ACTUAL OPERATOR CONDITIONS. THE RANGE OF VELOCITIES MIGHT BE RATHER SMALL (0 TO 10 FT./SEC.), WHEREAS THE RANGE OF ACCELERATION AND DECELERATION COULD BE LARGE.

AFTER INVESTIGATION OF MANY POSSIBLE APPROACHES FOR MAKING THESE MEASUREMENTS, IT APPEARED THAT THE DOPPLER EFFECT WITH SOUND AS THE RADIATION MEDIUM PRESENTED THE FEWEST OBSTACLES TO THE SUCCESSFUL DEVELOPMENT OF A WORK-MEASURING DEVICE. THE DEVICE DEVELOPED IS CALLED THE UNIVERSAL OPERATOR PERFORMANCE ANALYZER AND RECORDER (UNOPAR).

NEWELL, F.C. A STANDARDIZED SET OF SYMBOLS, NOTATION AND EQUATIONS OF MOTION TO BE USED IN C.A.L. FLIGHT RESEARCH REPORTS. FRM 161, CORNELL AERONAUTICAL LABORATORY, INC, FLIGHT RESEARCH DEPT., 24 NOV. 1952.

* ABSTRACT *

THIS STANDARD WAS BASED ON CAREFUL STUDY AND COMPARISON OF ALL CORNELL AERONAUTICAL LABORATORY REPORTS AS WELL AS THOSE OF THE N.A.C.A. RECOGNIZED TESTS AND AIR FORCE AND NAVY SPECIFICATIONS. IT WAS FELT TO BE A REASONABLE COMPROMISE IN LIGHT OF THE MANY USAGES THEN COMMON, ESPECIALLY IN REFERENCE TO THE STABILITY DERIVATIVE DEFINITIONS.

NEWELL, F.C. CRITERIA FOR ACCEPTABLE REPRESENTATION OF AIRPLANE DYNAMIC RESPONSES IN SIMULATORS USED FOR PILOT TRAINING. NAVTRADEVEN 1146-1, SEPTEMBER, 1962.

* ABSTRACT *

THIS REPORT ESTABLISHES THE APPLICATION OF MEASURED PILOT SENSITIVITIES TO AIRPLANE DYNAMIC-RESPONSE CHARACTERISTICS, AND TO AVIATION WEAPON SYSTEM TRAINER ACCEPTANCE CRITERIA.

REASONS WHY SIMULATORS SHOULD BE SUBJECTED TO TRANSIENT RESPONSE TESTS, THE ORIGIN AND APPLICABILITY OF HANDLING QUANTITIES EVALUATION DATA, AND THE EVALUATION PILOT ARE DISCUSSED. A SPECIFIC DISCUSSION OF EACH IMPORTANT LONGITUDINAL AND LATERAL-DIRECTIONAL HANDLING QUALITIES

PARAMETER IS GIVEN. PILOT SENSITIVITY TO EACH PARAMETER IS DETERMINED. ON THE BASIS OF PILOT SENSITIVITIES DETERMINED FROM THE STUDY, ACCURACY REQUIREMENTS FOR SIMULATORS ARE GIVEN AND DISCUSSED. A FUNDAMENTAL PREMISE OF THE STUDY IS THAT THE SIMULATOR REPRODUCE THE DYNAMICS OF THE AIRCRAFT WELL ENOUGH SO THAT THE PILOT IN TRAINING WILL USE THE SAME TECHNIQUES IN THE SIMULATOR AS HE WILL IN THE AIRCRAFT.

APPELL, F.D. AND SMITH, H.J. HUMAN TRANSFER CHARACTERISTICS IN FLIGHT AND GROUND SIMULATION FOR A ROLL TRACKING TASK NASA TN-D-5007, 1969.

* ABSTRACT *

TRANSFER CHARACTERISTICS FOR THREE PILOTS WERE MEASURED IN FLIGHT AND IN A GROUND SIMULATOR FOR A COMPENSATORY ROLL TRACKING TASK WITH SMALL BANK-ANGLE DISTURBANCES. THE FORCING FUNCTION IN EACH CASE CONSISTED OF THE SUM OF TEN SINE WAVES WITH A BANDWIDTH OF 1.5 RAD/SEC. A VARIABLE STABILITY T-33 PLANE WAS USED TO OBTAIN THE FLIGHT MEASUREMENTS. GROUND SIMULATOR MEASUREMENTS WERE WITH BOTH THE T-33 PLANE AND A GENERAL PURPOSE SIMULATOR WHICH USED A CONTACT ANALOGUE COLOR DISPLAY. THREE DIFFERENT CONTROLLED ELEMENTS WERE USED - TWO OF THESE WERE SIMPLE SINGLE DEGREE OF FREEDOM ELEMENTS THAT HAD PREVIOUSLY BEEN STUDIED. THE THIRD WAS A MULTIPLE DEGREE OF FREEDOM ELEMENT REPRESENTATIVE OF A PLANE WITH GOOD HANDLING QUALITIES, AND IT WAS CONSIDERED AND CONTROLLED AS A SINGLE DEGREE OF FREEDOM CONFIGURATION IN ROLL. ONLY THE MULTIPLE DEGREE OF FREEDOM CONTROLLED ELEMENT WAS FLOWN IN ACTUAL FLIGHT. TWO TECHNIQUES WERE USED TO GENERATE THE TRACKING TASK IN THE T-33 VIZ.,

1. THE FORCING FUNCTION WAS INJECTED DIRECTLY INTO THE DISPLAY AND
2. THE FORCING FUNCTION WAS INTRODUCED THROUGH THE AILERON CONTROL SYSTEM.

IN FLIGHT, THE FIRST CONFIGURATION HAD TO BE FLOWN UNDER IFR BECAUSE THE MOTION OF THE PLANE WAS NOT NECESSARILY IN HARMONY WITH THE INSTRUMENT-DISPLAYED MOTION. THE SECOND CONFIGURATION WAS FLOWN UNDER VFR AND THE MOTION WAS IN HARMONY WITH THE VISUAL DISPLAY. IN THE CONTACT-ANALOGUE SIMULATOR, THE DISPLAY APPROXIMATED THE VFR DISPLAY BUT THERE WERE NO NON-VISUAL CUES. THE RESULTS OF THE SIMPLE CONTROLLED ELEMENT EXPERIMENT AGREE WELL WITH PREVIOUS RESULTS. FOR THE MULTIPLE DEGREE OF FREEDOM CONTROLLED ELEMENT EXPERIMENT, A NOTICEABLE EFFECT OF DISPLAY WAS FOUND. FOR THIS EXPERIMENT, WHICH WAS RESTRICTED TO A SMALL DISTURBANCE BANK-ANGLE TRACKING TASK WITH GOOD CONTROLLED ELEMENT DYNAMICS, NON-VISUAL MOTION CUES APPEARED TO BE OF LESS IMPORTANCE THAN VISUAL CUES. THE THREE PILOTS EXHIBITED SIMILAR ADAPTATIONS TO EACH OF THE CONTROLLED ELEMENTS, ALTHOUGH ONE PILOT CONSISTENTLY USED A HIGHER GAIN IN THE T-33 GROUND AND FLIGHT TRIALS THAN DID EITHER OF THE OTHER TWO.

NAVTRAEQUIPCEN IH-298

NEWTON, J.M. 'TRAINING EFFECTIVENESS AS A FUNCTION OF SIMULATOR COMPLEXITY', USNTDC, PORT WASHINGTON, NEW YORK, TECHNICAL REPORT NAVTRADEVEN 458-1, SEPT, 1959. AD 230 996

* ABSTRACT *

THIS STUDY COMPARED THE EFFECTIVENESS OF TRAINING DEVICES HAVING FIVE DEGREES OF SIMULATION OF AN OPERATIONAL TASK. THE TASK SELECTED WAS ONE-MAN CONTROL IN COURSE AND DEPTH OF A HIGH SPEED SUBMARINE WITH PERFORMANCE MEASURES OF DEPTH CHANGING ONLY, COURSE CHANGING ONLY AND SIMULTANEOUS DEPTH AND COURSE CHANGING IN SUBMARINE STEERING AND DIVING TRAINERS.

ALTHOUGH THERE WERE GENERALLY NO SIGNIFICANT DIFFERENCES AMONG THE FIVE CONDITIONS, THE TREND WAS FOR THE MEAN SCORES TO BE RANKED IN ORDER OF SIMULATOR COMPLEXITY.

IT WAS CONCLUDED THAT EFFECTIVE TRAINING COULD BE PROVIDED WITH A SIMPLIFIED TRAINER AT A CONSIDERABLE COST REDUCTION.

NICHOLL, J. THE ECONOMICS OF THE ULTIMATE SIMULATOR. IN PROCEEDINGS TWO-DAY SYMPOSIUM ON FLIGHT TRAINING SIMULATORS FOR THE 70'S. 14TH/15TH OCTOBER, 1970, THE ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 0BG.

* ABSTRACT *

IF SIMULATORS DID NOT SAVE THE AIRLINES MONEY THEY WOULD NOT EXIST. IN THIS PAPER I HAVE GIVEN ROUGH APPROXIMATIONS OF COMPARATIVE COSTS FOR VARIOUS TYPES OF SIMULATORS, I.E., SIMPLE CURRENT STATE OF THE ART FULL SIMULATION, AND THE 'SUPER SIMULATOR'. IN THE PAST BOAC HAS OFTEN ACHIEVED VERY LOW TRANSITION AND RECURRENT TRAINING TIMES USING CHEAP ANALOGUE SIMULATORS WITH MOTION ONLY IN PITCH. CURRENT STATE OF THE ART SIMULATORS OFFER A CLEAR ADVANTAGE OVER THESE PREVIOUS SIMULATORS. HOWEVER, UNLESS THERE IS A BREAKTHROUGH TO A NEW TECHNOLOGY OFFERING LOWER PRICES FOR GREATER SOPHISTICATION, IT IS HIGHLY UNLIKELY THAT THE SUPER SIMULATOR WILL EVER BE PURCHASED BY ANY AIRLINE.

D. NUNEZ - MOTION SIMULATOR
PATENT NO. 3,890,722
FILED SEPT. 4, 1973 GRANTED JUNE 24, 1975

NO ABSTRACT

NAVTRAEQUIPCEN IH-298

BICANNAR, P.D.T. A LOW-COST ONE DEGREE OF FREEDOM FLIGHT MOTION SYSTEM. RAF INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH, HAMPSHIRE. IAM TECHNICAL MEMO 301, JUNE 1967.

* ABSTRACT *

A LOW COST FLIGHT MOTION SIMULATOR WAS REQUIRED BY THE PSYCHOLOGY SECTION OF THE ROYAL AIR FORCE INSTITUTE OF AVIATION MEDICINE IN ORDER TO MAKE A PRELIMINARY ASSESSMENT OF THE VALUE OF MOTION CUES AS AN AID TO REALISM IN FLIGHT SIMULATION, AND FOR OTHER RESEARCH WORK WHERE FLIGHT MOTION CUES WERE REQUIRED.

THE DESIGN PERFORMANCE WAS AS FOLLOWS:

PITCH AMPLITUDE:	+15 DEGREES, -10 DEGREES
MAXIMUM ANGULAR VELOCITY:	.35 RADIANS/SEC
MAXIMUM ANGULAR ACCELERATION	3 RADIANS/SEC SQUARED
FREQUENCY RESPONSE:	AS HIGH AS COULD BE AT A LOW COST, AND AT LEAST COMPARABLE WITH EXISTING SIMULATORS.

BICANNAR, P.D.T. A SIMULATOR CALLED HOPE. (AIR CLUES), FEB. 1968

* ABSTRACT *

THIS PAPER DESCRIBES THE DEVELOPMENT OF A LOW-COST FLIGHT MOTION SIMULATOR. THE SPECIFICATION CALLED FOR A DEVICE WITH FREEDOM IN PITCH ONLY, BUT DESIGNED SO THAT ROLL MOTION COULD BE ADDED LATER, IF REQUIRED. THE COMPUTER ASSOCIATED WITH IT WAS AN OLD SAUNDERS-ROE ANALOG COMPUTER AND THE COCKPIT WAS THE FRONT END OF A HUNTER F4 AIRCRAFT TRIMMED IN WEIGHT TO 600 POUNDS. FUTURE PLANS INCLUDE A VISUAL SYSTEM TO PROVIDE A VFR CAPABILITY. RESEARCH PLANNED FOR THE SIMULATOR WILL BE IN THE AREAS OF FIDELITY OF SIMULATION AND THE RESULTING TRAINING EFFECTIVENESS. IT IS HOPED THAT THIS RESEARCH WILL LEAD TO SIMULATORS BEING DESIGNED FOR MAXIMUM COST EFFECTIVENESS AND FOR THE CORRECT SHARING OF RESOURCES AMONG THE MANY ASPECTS OF SIMULATION PERFORMANCE WHICH ADD UP TO THE OPTIMUM REALISM AND TRAINING VALUE.

PREPAYER, R.W. MEASUREMENT CRITERIA IN MAN MACHINE SYSTEMS SIMULATION. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION REPORT NASA CR-257, JULY 1965.

* ABSTRACT *

THIS REPORT DESCRIBES SIMULATION, MODELS AND GAMES AS

ANALOGIES. THEY RESEMBLE IN SOME WAY SOMETHING ELSE ABOUT WHICH INFORMATION IS DESIRED. WE MAY THEREFORE MEASURE AN ANALOGY INSTEAD OF THE REAL-WORLD OBJECT. CRITICAL DIMENSIONS OF ANALOGIES ARE THE LEVEL OF ABSTRACTION AND THE FIDELITY OF SIMULATION. HOWEVER, IF THE OBJECT IS TO MEASURE, THE MOST CRITICAL ASPECT IS THE VALIDITY OF MEASUREMENT. UNFORTUNATELY, VALIDITY IS NOT ALWAYS A PRACTICAL CONCEPT. SINCE THE OBJECTIVE MEASUREMENT IS TO DERIVE INFORMATION, SIMULATION STUDIES ARE ANALYZED WITH RESPECT TO INFORMATION OBJECTIVE IN THE ATTEMPT TO DERIVE CRITERIA FOR MEASURE SELECTION. (AUTHOR)

ACKER, W.C. EL AL - PRE-FLIGHT REFLEX AND GUNNERY TRAINER
PATENT NO. 2,316,181
FILED SEP. 10, 1941 GRANTED APRIL 13, 1943

NO ABSTRACT

BDIARNA, A.V. 1 A SYNERGISTIC SIX DEGREE OF FREEDOM MOTION BASE SYSTEM. AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE PAPER 70-358.

* ABSTRACT *

COMPUTER SIMULATION HAS BECOME A VITAL PART OF THE DEVELOPMENT OF HIGHLY SOPHISTICATED AND EXPENSIVE MECHANICAL SYSTEMS. IT SHORTENS DEVELOPMENT TIME BY REVEALING PROBLEM AREAS DURING THE DESIGN PHASE THAT WOULD NORMALLY BE BROUGHT TO ATTENTION ONLY DURING THE TESTING PHASE, AND REDUCES THE PROBABILITY OF COSTLY SURPRISES LATE IN THE DEVELOPMENT OF THE SYSTEM. THIS PAPER DISCUSSES THE COMPUTER SIMULATION OF A SIX-DEGREE-OF-FREEDOM MOTION SYSTEM, IN PARTICULAR THE MOTION SYSTEM DYNAMICS AND HYDRAULIC SYSTEM. PARTICULAR ATTENTION IS GIVEN TO THE DERIVATION OF THE RELATIVELY SIMPLE EQUATIONS USED IN THE HYDRAULIC MATH MODEL, WHICH, ALONG WITH BASIC ASSUMPTIONS, RESULTED IN A REASONABLE SIMULATION OF THE MOTION SYSTEM. RESULTS FROM BOTH THE COMPUTER PROGRAM AND THE ACTUAL SYSTEM TEST ARE COMPARED TO SUBSTANTIATE THE ACCURACY OF THE COMPUTER SIMULATION. (AUTHOR)

BDIARNA, A.V. SIMULATION REQUIREMENTS AND TECHNOLOGY, VOLUME NO. 2 REPORT B. SIMULATION OF MOTION. LINK/DIVISION/SINGER COMPANY BINGHAMTON, N.Y. REPORT NO. LR-23918-2, SEPTEMBER 1970

* ABSTRACT *

THIS STUDY WAS UNDERTAKEN TO DETERMINE WHAT KIND OF MOTION SYSTEM, IF ANY, SHOULD BE RECOMMENDED FOR USE WITH GROUND BASED

FLIGHT SIMULATORS IN UPT 7590 IN ORDER TO PROVIDE THE MOST EFFECTIVE TRAINING PROGRAM. A SURVEY OF THE LITERATURE WAS CONDUCTED TO INVESTIGATE THE ADVANTAGES OF MOTION; THE AVAILABILITY OF THE VALUES REQUIRED FOR MINIMUM AND MAXIMUM ACCELERATION FOR THE REQUIRED MOTION CUES; THE DRIVE SIGNAL PHILOSOPHIES CURRENTLY BEING DISCUSSED; AND EQUATIONS RELATING THESE MOTION PARAMETERS TO THE ACTUAL HARDWARE. THE EFFECTS OF VARIOUS MOTION PARAMETERS ON TRAINING REQUIREMENTS WERE EXAMINED, WHERE RESEARCH DATA ON MOTION SYSTEMS WERE NOT AVAILABLE, FIRST HAND EXPERIENCE IN THE DEVELOPMENT OF MOTION SYSTEMS WAS USED. HISTORICAL COST FIGURES WERE USED TO CONSTRUCT A REGRESSION ANALYSIS CURVE ON MOTION SYSTEMS. OTHER SIGNIFICANT CONSIDERATIONS SUCH AS TRAINING VALUES, COMMONALITY OF PARTS AND WEIGHT REQUIREMENTS WERE ALSO CONSIDERED.

FROM THIS STUDY IT IS CONCLUDED THAT UPT 7590 FLIGHT SIMULATORS SHOULD INCORPORATE A SIX DEGREE OF FREEDOM SYNERGISTIC MOTION SYSTEM WITH A 4X STROKE. IN ADDITION, AREAS WHERE FURTHER DEFINITIVE DATA IS NEEDED ARE IDENTIFIED AND THE USE OF THE AIRCRAFT SIMULATION FOR UNDERGRADUATE PILOT TRAINING FACILITY IS RECOMMENDED TO PROVIDE THESE DATA ON A PRIORITY BASIS.

BLDFIELD, D. ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH, INSTRUMENTATION AND ELECTRONICS DIVISION. 1966. (PERSONAL COMMUNICATION REF TECH MEMO IN PRESS.)

* ABSTRACT *

FOUR TEST PILOTS FLEW A VTOL HOVER TASK, WITHOUT AUTO-STABILIZATION, USING A HEAD-UP DISPLAY IN A SIMULATOR WITH PITCH FREEDOM. APPROPRIATELY RESPONSIVE MOTION SIMULATION WAS HELPFUL, WHILE THE INTRODUCTION OF A MOTION RESPONSE LAG OF ABOUT 1/2 SEC PRODUCED PERFORMANCE WORSE THAN IN FIXED BASE, ADVERSE PILOT COMMENT, AND NAUSEA IN 3 PILOTS.

ARMSTRY, C.C. MODEL OF HUMAN DYNAMIC ORIENTATION PH D THESIS, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, MIT, 1974.

* ABSTRACT *

THE DYNAMICS ASSOCIATED WITH THE PERCEPTION OF ORIENTATION WERE MODELLED FOR NEAR-THRESHOLD AND SUPRATHRESHOLD VESTIBULAR STIMULI. A MODEL OF THE INFORMATION AVAILABLE AT THE PERIPHERAL SENSORS WHICH WAS CONSISTENT WITH AVAILABLE NEUROPHYSIOLOGIC DATA WAS DEVELOPED AND SERVED AS THE BASIS FOR THE MODELS OF THE PERCEPTUAL RESPONSES. AS A PRELIMINARY ASSUMPTION THE CENTRAL PROCESSOR WAS ASSUMED TO UTILIZE THE INFORMATION FROM THE PERIPHERAL SENSORS IN AN OPTIMAL (MINIMUM MEAN SQUARE ERROR) MANNER TO PRODUCE THE PERCEPTUAL ESTIMATES

OF DYNAMIC ORIENTATION. THIS ASSUMPTION, COUPLED WITH THE MODELS OF SENSORY INFORMATION, DETERMINED THE FORM OF THE MODEL, FOR THE CENTRAL PROCESSOR. COMPARISON OF MODEL RESPONSES WITH DATA FROM PSYCHOPHYSICAL EXPERIMENTS INDICATED THAT WHILE LITTLE OR NO CENTRAL PROCESSING MAY BE OCCURRING FOR SIMPLE SUPRATHRESHOLD CANAL STIMULATION, A SIGNIFICANT PORTION OF THE DYNAMIC RESPONSE TO TRANSLATIONAL ACCELERATIONS MUST BE ATTRIBUTED TO THE CENTRAL PROCESSING OF OTOLITH INFORMATION.

THE FUNDAMENTAL MECHANISM WHICH UNDERLIES THE PHENOMENON OF VESTIBULAR THRESHOLDS WAS STUDIED EXPERIMENTALLY BY TESTING THE RESPONSE OF SUBJECTS TO A NEAR THRESHOLD STIMULUS CONSISTING OF A VELOCITY STEP-RAMP PROPORTIONAL TO THE SUM OF THE SUBJECT'S VELOCITY STEP AND ACCELERATION STEP THRESHOLDS. EXPERIMENTAL RESULTS INDICATED THAT CANAL THRESHOLDS COULD BE ACCOUNTED FOR BY A MODEL OF CENTRAL PROCESSING CONSISTING ONLY OF AN OPTIMAL PROCESSING OF AFFERENT FIRING RATES IN ADDITIVE NOISE WITH NO NECESSITY FOR PERIPHERAL DEAD ZONE NONLINEARITIES. QUANTITATIVE MODELS OF THRESHOLD DETECTION WERE DEVELOPED WHICH CORRECTLY PREDICTED THRESHOLD LEVELS (75% CORRECT DETECTION) AND RESPONSE LATENCIES FOR ROTATIONAL STIMULI. IT WAS FOUND THAT THE SAME DETECTOR COULD BE USED TO MODEL THE THRESHOLD RESPONSES RESULTING FROM TRANSLATIONAL STIMULI.

THE ILLUSIONS OF STATIC ORIENTATION WERE STUDIED AND IT WAS SHOWN THAT THEY WERE CONSISTENT WITH A SIMPLE VECTOR TRANSFORMATION WHICH COULD BE ASSOCIATED WITH DIFFERENCES IN THE PROCESSING OF SIGNALS ARISING FROM STIMULI IN AND STIMULI PERPENDICULAR TO THE UTRICLE PLANE. A MODEL WAS DEVELOPED WHICH INCORPORATED THIS DIFFERENCE AND WHICH WAS CAPABLE OF PREDICTING THE PERCEPTION OF ORIENTATION IN AN ARBITRARY STATIC SPECIFIC FORCE ENVIRONMENT.

THE PROBLEM OF INTEGRATING INFORMATION FROM THE SEMICIRCULAR CANALS AND THE OTOLITHS TO PREDICT THE PERCEPTUAL RESPONSE TO MOTIONS WHICH STIMULATE BOTH ORGANS WAS STUDIED. A MODEL WAS DEVELOPED WHICH WAS SHOWN TO BE USEFUL IN PREDICTING THE PERCEPTUAL RESPONSE TO MULTI-SENSORY STIMULI. (AUTHOR)

 ARMSBY, C.C. AND YOUNG, L.R. PERCEPTION OF STATIC ORIENTATION IN A CONSTANT GRAVITOINERTIAL ENVIRONMENT. IN PRESS IN AERO-SPACE AND ENVIRONMENTAL MEDICINE.

* ABSTRACT *

HUMAN PERCEPTION OF THE DIRECTION OF THE GRAVITATIONAL VERTICAL IN THE ABSENCE OF VISUAL CUES, IS BASED PRINCIPALLY ON VESTIBULAR INFORMATION. THIS PAPER EXAMINES THE SETTING OF THE APPARENT VERTICAL (SUBJECTIVE INDICATION OF THE EARTH VERTICAL) UNDER QUASI-STATIC CONDITIONS, IN WHICH THE EFFECTS OF BODY ANGULAR ACCELERATIONS ARE ASSUMED TO HAVE DECAYED TO A

NEGLECTIBLE LEVEL. THE VARIETY OF EXISTING DATA IS SHOWN TO BE CONSISTENT WITH A SIMPLE VECTOR TRANSFORMATION WHICH COULD BE ASSOCIATED WITH DIFFERENCES IN THE TREATMENT OF SIGNALS ARISING FROM STIMULI IN AND STIMULI PERPENDICULAR TO THE UTRICLE PLANE. THE DYNAMIC ASPECTS OF INTERACTIONS BETWEEN SEMI-CIRCULAR CANAL AND OTOLITH SYSTEM INFORMATION ARE DISCUSSED IN A SEPARATE PAPER.

THIS PAPER ATTEMPTS TO UNIFY THE RESULTS OBSERVED AND RELATE THEM TO VESTIBULAR FUNCTION BY:

1. DEMONSTRATING THAT A RELATIVELY SIMPLE CATEGORIZATION OF THE STIMULUS ENABLES ONE TO PREDICT QUALITATIVELY THE DEVIATIONS OF THE PERCEIVED VERTICAL FROM THE TRUE DIRECTION OF SPECIFIC FORCE.
2. CONSTRUCTION OF A MODEL CONSISTENT WITH BOTH THE PHYSICAL STRUCTURE OF THE OTOLITH SENSORS AND WITH THE ABOVE CATEGORIZATION OF STIMULI WHICH PREDICTS WITH REASONABLE ACCURACY THE PERCEPTIONS OF ORIENTATION RESULTING FROM ARBITRARY CONSTANT SPECIFIC FORCE STIMULI.

 REMSLEY, C.C. AND YOUNG, L.R. INTEGRATION OF SEMICIRCULAR CANAL AND OTOLITH INFORMATION FOR MULTISENSORY STIMULI. IN PRESS IN THE JOURNAL OF MATHEMATICAL BIOSCIENCES.

* ABSTRACT *

IN THIS PAPER THE SUBJECTIVE RESPONSES TO MULTI-SENSORY STIMULI (THOSE STIMULI WHICH SIMULTANEOUSLY EXCITE THE SEMICIRCULAR CANALS AND THE OTOLITHS) ARE MODELLED AND THE PREDICTIONS OF THIS MODEL COMPARED TO THE APPROPRIATE EXPERIMENTAL DATA. PREVIOUS QUANTITATIVE MODELS HAVE DEALT ALMOST EXCLUSIVELY WITH THE RESPONSE TO NONINTERACTING STIMULI (THOSE STIMULI WHICH EXCITE EITHER THE OTOLITHS OR THE SEMICIRCULAR CANALS, BUT NOT BOTH). WHEN THE STIMULUS CLASS IS GENERALIZED TO INCLUDE ANY COMBINATION OF ROTATIONAL ACCELERATION IN THREE AXES A NUMBER OF SIGNIFICANT PROBLEMS ARISE. AFTER THESE PROBLEMS ARE DISCUSSED, A MATHEMATICAL MODEL IS DEVELOPED OF THE PERCEPTION OF DYNAMIC ORIENTATION WHICH RESULTS FROM THE COMBINED EFFECT OF ARBITRARY ANGULAR AND TRANSLATIONAL ACCELERATIONS. TO ILLUSTRATE THE USEFULNESS OF THE MODEL FOR THE CONCEPTUAL UNDERSTANDING OF RESPONSES TO MULTI-SENSORY STIMULI, THREE EXAMPLES OF THE QUALITATIVE APPLICATIONS OF THE MODEL ARE GIVEN. THE PAPER CONCLUDES BY PRESENTING THE QUANTITATIVE PREDICTIONS OF THE MODEL ALONG WITH FREQUENCY RESPONSE OF THE MODEL FOR SMALL PITCH AND ROLL OSCILLATIONS.

NAVTRAEQUIPCEN IH-298

E.G. PANCBE - MOTION SYSTEM FOR AN AIRCRAFT FLIGHT SIMULATOR
PATENT NO. 3,281,962
FILED JULY 31, 1964 GRANTED NOV. 1, 1966

NO ABSTRACT

E.G. PANCBE ET AL - MECHANICAL MOTION SYSTEM
PATENT NO. 3,451,146
FILED DEC. 9, 1966 GRANTED JUNE 24, 1969

NO ABSTRACT

E.G. PANCBE - MOTION SYSTEM
PATENT NO. 3,619,911
FILED MAY 19, 1969 GRANTED NOV. 16, 1971

NO ABSTRACT

E.G. PANCBE - MOTION SIMULATOR
PATENT NO. 3,577,655
FILED MAY 19, 1969 GRANTED MAY 4, 1971

NO ABSTRACT

PARKER, D.M., SCHAFFER, J., AND COHEN, E. THE EFFECT OF PAST
EXPERIENCE ON MOTION SICKNESS PRODUCED BY VISUAL STIMULI. J.
OF GENERAL PSYCHOL., 87, 1972, 65-68.

* ABSTRACT *

SKIN CONDUCTANCE MEASURES WERE TAKEN FROM THE VULAR FOREARM SUR-
FACES OF 24 SUBJECTS WHO VIEWED FILMS DEPICTING THE MOVING ENVI-
RONMENT AS VIEWED ON A VESSEL AT SEA. THOSE WHO HAD LITTLE EX-
PERIENCE WITH THE SEA WERE LESS AFFECTED THAN WERE THOSE WITH
RELATIVELY GREATER EXPERIENCE.

THE RESULTS WERE TAKEN TO SUPPORT THE CONCEPT OF CONDITIONABILI-
TY OF VESTIBULAR MECHANISMS AND ALSO TO SUPPORT THE ALTERNATIVE
CONCEPT OF HIGHER LEVEL CONDITIONING WITH CORTICIFUGAL EFFECTS
UPON BRAIN STEM TRIGGER MECHANISMS. FURTHER RESEARCH WAS SUG-
GESTED TO RESOLVE THE QUESTION.

 PARKER, J.F.
 'VIBRASTRONAUTICS DATA BOOK', SECOND EDITION, PARKER, J.F., JR.
 AND WEST, VITA R. (EDS.) NASA SP-3006, SCIENTIFIC AND TECHNICAL
 INFORMATION OFFICE, NATIONAL AERONAUTICS AND SPACE ADMINISTRA-
 TION, WASHINGTON, D.C., 1973.

* ABSTRACT *

THIS EFFORT REPRESENTS AN UPDATING AND EXPANSION OF AN EARLIER
 DOCUMENT PREPARED FOR THE NATIONAL AERONAUTICS AND SPACE
 ADMINISTRATION IN 1964 BY WEBB ASSOCIATES.

THIS REVISION WAS PREPARED BY BIO TECHNOLOGY, INC. UNDER
 CONTRACT TO THE OFFICE OF NAVAL RESEARCH WITH SUPPORT FROM THE
 NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TO PUT WITHIN ONE
 COVER A GOOD REPRESENTATION OF APPLIED RESEARCH DATA FROM THE
 VARIOUS LIFE SCIENCES, ESPECIALLY FROM APPLIED PHYSIOLOGY. THE
 CHAPTERS ON ACCELERATION, VIBRATION, THE VESTIBULAR SYSTEM,
 VISION, AND HUMAN CONTROL CAPABILITIES ARE PARTICULARLY
 APPLICABLE TO PROBLEMS IN MOTION SIMULATION.

 PARKS, D.L. A COMPARISON OF SINUSOIDAL AND RANDOM VIBRATION
 EFFECTS ON HUMAN PERFORMANCE. ROEING DOCUMENT D3-3512-2, JULY
 1961.

* ABSTRACT *

TEN MALE SUBJECTS PERFORMED A COMPLEX TASK DURING VERTICAL
 VIBRATION IN A PRELIMINARY STUDY TO COMPARE PERFORMANCE WITH
 SINUSOIDAL, CONSTANT PERIOD RANDOM AMPLITUDE, AND RANDOM (AIR-
 CRAFT TURBULENCE) VIBRATION. PERFORMANCE ON THE THREE SUBTASKS
 VARIED: PERFORMANCE ON A TRACKING TASK WITH DELAYED CONTROL-
 DISPLAY FEEDBACK WAS DIFFERENTLY AFFECTED WITHOUT FEEDBACK
 DELAY; AND RESPONSE TIME DID NOT CHANGE.

RESULTS WERE ANALYZED FOR CONSISTENT TRENDS IN VIBRATION
 EFFECTS WHICH COULD BE CORRELATED WITH MECHANICAL AND
 PSYCHOLOGICAL DEFINITIONS OF VIBRATION FOR EVIDENCE OF A HUMAN
 PERFORMANCE TRANSFER FUNCTION FOR VIBRATION. PSYCHOLOGICAL AND
 AMPLITUDE BASES FOR THIS FUNCTION COULD NOT BE FOUND.
 VIBRATION ACCELERATION (G) EFFECTS WERE NOT CLEAR, AND RMS
 AMPLITUDE POWER WAS CORRELATED WITH CONSTANCIES IN PERFORMANCE.
 IT WAS SUGGESTED THAT TESTING COMBINATIONS OF RMS AND FREQUENCY
 (AND RELATED FACTORS) COULD LEAD TO A PERFORMANCE TRANSFER
 FUNCTION PERMITTING TRANSFORMATION OF HUMAN PERFORMANCE DATA
 FROM SINUSOIDAL TO OPERATIONAL VIBRATING ENVIRONMENTS.

PARKS, D.L. 'DEFINING HUMAN REACTION TO WHOLE-BODY VIBRATION'.
'HUMAN FACTORS', OCTOBER 1962.

* ABSTRACT *

STANDARDIZED SUBJECTIVE REACTION LEVELS FOR VIBRATION WERE DERIVED USING 16 PHYSICALLY FIT MALE SUBJECTS AGED 25 TO 40. A CONTROLLED ENVIRONMENT, HARD SEAT, AND LAP BELT WERE USED TO AVOID DISTRACTIONS AND OTHER INTERFERENCES FROM ENVIRONMENTAL SOURCES, TO INSURE MOST COMPLETE TRANSMISSION OF THE SAME INPUT TO ALL SUBJECTS, AND TO CONTROL POSSIBLE FREQUENCY PHASE SHIFTS BETWEEN THE SUBJECT AND THE SEAT.

FOUR VIBRATION LEVELS WERE DERIVED: (1) DEFINITELY PERCEPTIBLE, (2) MILDLY ANNOYING, (3) EXTREMELY ANNOYING, (4) ALARMING. THE LEVELS WERE SIGNIFICANTLY DIFFERENT. EACH LEVEL VARIED IN ACCELERATION AS A FUNCTION OF FREQUENCY. DATA DESCRIBING VIBRATION EFFECTS ON VISION, BY LEVEL, IS PRESENTED TO INDICATE THE VALIDITY OF THE LEVELS FOR USE AS STANDARD VIBRATION CONDITIONS IN TESTING HUMAN PERFORMANCE.

FARRISH, R.V., DIEUDONNE, J.E. AND MARLIN, D.J.JR. 'MOTION SOFTWARE FOR A SYNERGISTIC SIX-DEGREE-OF-FREEDOM MOTION BASE'.
NASA TN-7350, 1973.

* ABSTRACT *

COMPUTER SOFTWARE FOR THE CONVERSION OF FIXED-BASE SIMULATIONS INTO MOVING-BASE SIMULATIONS UTILIZING A SYNERGISTIC SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR HAS BEEN DEVELOPED. THIS SOFTWARE INCLUDES AN ACTUATOR EXTENSION TRANSFORMATION, INVERSE ACTUATOR, EXTENSION TRANSFORMATION, INVERSE ACTUATOR EXTENSION TRANSFORMATION, A CENTROID TRANSFORMATION AND A WASHOUT CIRCUIT. PARTICULAR EMPHASIS IS PLACED UPON THE WASHOUT CIRCUITRY AS ADAPTED TO FIT THE SYNERGISTIC MOTION SIMULATOR. THE DESCRIPTION OF THE WASHOUT CIRCUITRY AND ILLUSTRATION BY MEANS OF A SAMPLE FLIGHT EMPHASIZE THAT TRANSLATIONAL CUE REPRESENTATION MAY BE OF GOOD FIDELITY, BUT CARE IN THE SELECTION OF PARAMETERS IS VERY NECESSARY, PARTICULARLY IN REGARD TO ANOMALOUS ROTATIONAL CUES.

FARRISH, R.V. AND DIEUDONNE, J.E.
FIRST ORDER WASHOUT FOR A SINGLE DEGREE OF FREEDOM UTILIZING A LINEAR FILTER, A NONLINEAR ADAPTIVE FILTER AND A DIGITAL CONTROLLER.
LANGLEY WORKING PAPER, LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA LWF-1093, JAN 1973.

* ABSTRACT *

THE PROBLEM OF PROVIDING REALISTIC AND MEANINGFUL MOTION CUES TO A SIMULATOR PILOT WHILE SATISFYING THE PHYSICAL CONSTRAINTS OF A MOTION BASE IS TREATED USING A LINEAR FILTER, A NONLINEAR ADAPTIVE FILTER, AND A DIGITAL CONTROLLER FOR A ONE DEGREE OF FREEDOM INVESTIGATION. RESULTS DEMONSTRATE THAT BETTER FIDELITY OF MOTION, IN TERMS OF AMPLITUDE ERROR, PHASE ERROR, AND ANOMALOUS CUES, IS OBTAINED WITH THE DIGITAL CONTROLLER THAN WITH EITHER THE LINEAR FILTER OR THE NONLINEAR ADAPTIVE FILTER.

FARRISH, R.V., DIEUDONNE, J.E., MARTIN, D.J., AND BOWLES, R.L. COORDINATED ADAPTIVE FILTERS FOR MOTION SIMULATORS. PROCEEDING OF THE 1973 SUMMER COMPUTER SIMULATION CONFERENCE, SIMULATION COUNCILS, INC. JULY 1973, PP. 295-300.

* ABSTRACT *

A NEW APPROACH TO PROVIDING MOTION DRIVE SIGNALS TO A FLIGHT SIMULATOR UTILIZING COORDINATED ADAPTIVE FILTERS IS PRESENTED. SOME MOTIVATION FOR THE USE OF COORDINATED WASHOUT IS DISCUSSED, ALONG WITH CONDITIONS THAT DETERMINE THE BURDEN OF COORDINATION. THE COORDINATED ADAPTIVE FILTERS ARE DERIVED BASED ON CONTINUOUS STEEPEST DESCENT, AND THE APPLICATION OF THE FILTERS TO SIMULATED FLIGHT DATA IS DEMONSTRATED.

FARRISH, R.V., DIEUDONNE, J.E., MARTIN, D.J. JR, AND BOWLES, R.L. COORDINATED ADAPTIVE WASHOUT FOR MOTION SIMULATORS, AIAA PAPER NO. 73-930, PALM ALTO, CALIFORNIA, SEPTEMBER 1973

* ABSTRACT *

THIS PAPER INTRODUCES A NEW METHOD OF PROVIDING MOTION CUES TO A MOVING BASE SIX-DEGREE-OF-FREEDOM FLIGHT SIMULATOR UTILIZING NONLINEAR FILTERS. COORDINATED ADAPTIVE FILTERS, USED TO COORDINATE TRANSLATIONAL AND ROTATIONAL MOTION, ARE DERIVED BASED ON THE METHOD OF CONTINUOUS STEEPEST DESCENT, AND THE BASIC CONCEPT OF THE DIGITAL CONTROLLERS USED FOR THE UNCOORDINATED HEAVE AND YAW CUES IS ALSO PRESENTED. THE COORDINATED ADAPTIVE WASHOUT METHOD IS ILLUSTRATED BY AN APPLICATION IN A SIX-DEGREE-OF-FREEDOM FIXED-BASE ENVIRONMENT. *ALSO IN J. OF AIRCRAFT, VOL 12, NO. 1, JAN 1975

FARRISH, R.V., DIEUDONNE, J.E., MARTIN, D.J., AND COPELAND, J.L. COMPENSATION BASED ON LINEARIZED ANALYSIS FOR A SIX-DEGREE-OF-FREEDOM MOTION SIMULATOR, LANGLEY RESEARCH CENTER, HAMPTON, VIRGINIA, NASA TECHNICAL NOTE TN-D-7349, NOV 1973.

* ABSTRACT *

THE INERTIAL RESPONSE CHARACTERISTICS OF A SYNERGISTIC, SIX-DEGREE-OF-FREEDOM MOTION BASE ARE PRESENTED IN TERMS OF AMPLITUDE RATIO AND PHASE LAG AS FUNCTIONS OF FREQUENCY DATA FOR THE FREQUENCY RANGE OF INTEREST (0-2HZ) IN REAL TIME, DIGITAL FLIGHT SIMULATORS. THE NOTCH FILTERS WHICH SMOOTH THE DIGITAL DRIVE SIGNALS TO CONTINUOUS DRIVE SIGNALS ARE PRESENTED. THE EXISTENCE OF AN INVERSE TRANSFORMATION THAT CONVERTS ACTUATOR EXTENSIONS INTO INERTIAL POSITIONS MAKES IT POSSIBLE TO GATHER THE RESPONSE DATA IN THE INERTIAL AXIS SYSTEM.

FARRISH, R.V., FOLCK, J.A., AND MARTIN, D.J. JR. EMPIRICAL COMPARISON OF A FIXED-BASE AND A MOVING-BASE SIMULATION OF A HELICOPTER ENGAGED IN VISUALLY CONDUCTED SLALOM RUNS. NASA 'LANGLEY RESEARCH CENTER TECHNICAL NOTE' D-8424, MAY 1977.

* ABSTRACT *

AN EVALUATION STUDY HAS BEEN COMPLETED OF COMBINED VISUAL, MOTION AND AURAL CUES FOR A HELICOPTER ENGAGED IN VISUALLY CONDUCTED SLALOM RUNS AT LOW ALTITUDE. THE EVALUATION OF THE VISUAL AND AURAL CUES WAS SUBJECTIVE, WHEREAS THE MOTION CUES WERE EVALUATED BOTH SUBJECTIVELY AND OBJECTIVELY. SUBJECTIVE OPINION AND OBJECTIVE DATA CONFLICTED IN THE DETECTION OF DIFFERENCES IN THE PERFORMANCE OF A PRIMARY AND SECONDARY TASK UNDER MOTION AND NO MOTION CONDITIONS. SUBJECTIVELY, DIFFERENCES IN PERFORMANCE WERE EXPECTED, AND OBJECTIVELY, NO SIGNIFICANT DIFFERENCES WERE DETECTED. HOWEVER, SUBJECTIVE AND OBJECTIVE RESULTS COINCIDED IN THE AREA OF CONTROL ACTIVITY. GENERALLY, LESS CONTROL ACTIVITY IS PRESENT UNDER MOTION CONDITIONS THAN UNDER FIXED-BASE CONDITION, A FACT ATTRIBUTED SUBJECTIVELY TO THE FEELING OF REALISTIC LIMITATIONS OF A MACHINE (HELICOPTER) GIVEN BY THE ADDITION OF MOTION CUES. THE OBJECTIVE DATA ALSO REVEALED THAT THE SLALOM RUNS WERE CONDUCTED AT SIGNIFICANTLY HIGHER ALTITUDES UNDER MOTION CONDITIONS THAN UNDER FIXED-BASE CONDITIONS.

FARRISH, R.V. AND MARTIN, D.J. JR. EMPIRICAL COMPARISON OF A LINEAR AND A NONLINEAR WASHOUT FOR MOTION SIMULATORS. PRESENTED AT THE AIAA 13TH AEROSPACE SCIENCES MEETING, PASADENA, CALIFORNIA, JANUARY 20-22, 1975.

* ABSTRACT *

THE SUBJECTIVE OPINIONS GATHERED FROM SEVEN PILOTS IN THE PROCESS OF COMPARING A LINEAR AND A NONLINEAR WASHOUT FOR MOTION SIMULATORS REVEAL AN IMPORTANT ADVANCE IN MOTION CUE PRESENTATION. THE ADVANCE IS NOT IN THE INCREASED CUE PROVIDED BY THE NONLINEAR FILTER OVER A LINEAR FILTER FOR THE

SAME AMOUNT OF MOTION BASE TRAVEL, BUT RATHER IN THE ELIMINATION OF FALSE ROTATIONAL RATE CUES PRESENTED BY LINEAR FILTERS.

FARRISH, R.V. AND MARTIN, DENNIS J. JR.
EVALUATION OF A LINEAR WASHOUT FOR SIMULATOR MOTION CUE PRESENTATION DURING LANDING APPROACH. NASA TECHNICAL NOTE TN-D-8036
OCTOBER 1975.

* ABSTRACT *

THE COMPARISON OF A FIXED-BASE VERSUS A FIVE-DEGREE-OF-FREEDOM MOTION BASE SIMULATION (THE HEAVE CUE WAS NOT PRESENTED) OF A 737 CONVENTIONAL TAKE-OFF AND LANDING (CTOL) AIRCRAFT PERFORMING INSTRUMENT LANDING SYSTEM (ILS) LANDING APPROACHES HAS BEEN USED TO EVALUATE A LINEAR MOTION WASHOUT TECHNIQUE. THE FACT THAT THE PILOTS FELT THAT THE ADDITION OF MOTION INCREASED THE PILOT WORKLOAD AND THIS INCREASE WAS NOT REFLECTED IN THE OBJECTIVE DATA RESULTS, INDICATES THAT MOTION CUES, AS PRESENTED, ARE NOT A CONTRIBUTING FACTOR TO ROOT-MEAN-SQUARE (RMS) PERFORMANCE DURING THE LANDING APPROACH TASK. SUBJECTIVE RESULTS FROM STANDARD MANEUVERING ABOUT STRAIGHT AND LEVEL FLIGHT FOR SPECIFIC MOTION CUE EVALUATION REVEALED THAT THE LONGITUDINAL CHANNELS (PITCH AND SURGE) AND POSSIBLY THE YAW CHANNEL PRODUCE ACCEPTABLE MOTIONS. THE ROLL CUE REPRESENTATION, INVOLVING BOTH ROLL AND SWAY CHANNELS, WAS FOUND TO BE INADEQUATE FOR LARGE ROLL INPUTS, AS USED FOR EXAMPLE, IN TURN ENTRIES.

FARRISH, R.V. AND MARTIN, D.J. JR.
THE COMPARISON OF A LINEAR AND A NONLINEAR WASHOUT FOR MOTION SIMULATORS UTILIZING OBJECTIVE AND SUBJECTIVE DATA FROM CTOL TRANSPORT LANDING APPROACHES TN-D-8157, 1976, NASA.

* ABSTRACT *

OBJECTIVE AND SUBJECTIVE DATA GATHERED IN THE PROCESS OF COMPARING A LINEAR AND A NONLINEAR WASHOUT FOR MOTION SIMULATORS REVEAL THAT THERE IS NO DIFFERENCE IN THE PILOT-PERFORMANCE MEASUREMENTS USED DURING INSTRUMENT-LANDING-SYSTEM (ILS) APPROACHES WITH A BEING 737 CONVENTIONAL TAKE-OFF AND LANDING (CTOL) AIRPLANE BETWEEN FIXED-BASE LINEAR-WASHOUT, AND NONLINEAR-WASHOUT OPERATIONS. HOWEVER, THE SUBJECTIVE OPINIONS OF THE PILOTS REVEAL AN IMPORTANT ADVANCE IN MOTION-CUE REPRESENTATION. THE ADVANCE IS NOT IN THE INCREASED CUE AVAILABLE OVER A LINEAR FILTER FOR THE SAME AMOUNT OF MOTION BASE TRAVEL BUT RATHER IN THE ELIMINATION OF FALSE ROTATIONAL RATE CUES PRESENTED BY LINEAR FILTERS.

FARRISH, R.V., ROLLINS, J.D., AND MARTIN, D.J., JR.
VISUAL/MOTION SIMULATION OF CTOL FLARE AND TOUCHDOWN COMPARING
DATA OBTAINED FROM TWO MODEL BOARD DISPLAY SYSTEMS. AIAA PAPER
NO. 76-010 PRESENTED AT THE AIAA VISUAL MOTION SIMULATION CON-
FERENCE, DAYTON, OHIO, APRIL 26-28, 1976.

* ABSTRACT *

ACQUISITION OF A MODERN TERRAIN MODEL BOARD DISPLAY SYSTEM FOR
'OUT-THE-WINDOW' SCENE PRESENTATION HAS ALLOWED FOR THE
REPETITION OF AN EVALUATION STUDY OF COMBINED VISUAL/MOTION
CUES FOR CTOL FLARE AND TOUCHDOWN CONTROL THAT WAS ORIGINALLY
CARRIED OUT ON A 1965 VINTAGE LANDING DISPLAY SYSTEM. THE
MOTION DRIVE SYSTEM USED IN BOTH STUDIES WAS A NONLINEAR
COORDINATED ADAPTIVE WASHOUT BASED ON THE METHOD OF CONTINUOUS
STEEPEST DESCENT OPTIMIZATION.

COMPARISONS OF THE RESULTS OF THE STUDIES PRESENT FLARE AND
TOUCHDOWN DATA, AS WELL AS DYNAMIC RESPONSE DATA FROM THE TWO
VISUAL LANDING SYSTEMS.

THE NEW VISUAL SYSTEM ALSO ALLOWED FOR THE REPETITION UNDER
VISUAL CONDITIONS, OF A SUBJECTIVE COMPARISON OF A LINEAR AND A
NONLINEAR MOTION WASHOUT METHOD DONE PREVIOUSLY UNDER
INSTRUMENT CONDITIONS.

PERRY, D.F. 'FLIGHT SIMULATORS AND THE STUDY OF AIRCRAFT HAND-
LING CHARACTERISTICS'. ROYAL AIRCRAFT ESTABLISHMENT, BEDFORD,
TOLS-7, 1962.

* ABSTRACT *

CONCLUSION, BASED ON A STUDY OF US WORK, THAT SIMULATOR
MOTION CUES CAN BE IMPORTANT FOR SOME TASKS ALTHOUGH PROBABLY
NOT ESSENTIAL FOR THE COMPARATIVELY GENTLE ONES OF TAKE-OFF AND
LANDING.

PERRY, D.F. 'PILOTED FLIGHT SIMULATION TECHNIQUES'. PAPER AND
REPLIES TO QUESTIONS AT AERODYNAMICS CONFERENCE, ROYAL AIRCRAFT
ESTABLISHMENT, FARNBOROUGH, ENGLAND. 1965.

* ABSTRACT *

MOTION IS FELT TO KEEP PILOT INFORMED, ALMOST SUBCONSCIOUSLY,
OF DISTURBANCE TO AIRCRAFT'S TRIMMED STATE. LACK OF YAW MOTION
IS ALMOST CERTAINLY REASON FOR DISCREPANCIES BETWEEN FLIGHT AND
SIMULATOR FINDINGS IN STUDIES OF VTOL HOVER AND SLENDER DELTA
YAW CHARACTERISTICS. IT WAS NECESSARY TO INTRODUCE A 10X
INCREASE IN YAW DAMPING INTO STATIC SIMULATION BEFORE PILOTS

THOUGHT THE VTOL HOVER TASK DEMANDED THE SAME WORKLOAD AS IN FLIGHT.

FERRY, D.F. FLIGHT SIMULATION - SOME ASPECTS OF ITS USE FOR STUDIES OF AIRCRAFT HANDLING QUALITIES. 'ROYAL AIRCRAFT ESTABLISHMENT' TECHNICAL MEMORANDUM NO. AERO 952, SEPTEMBER 1966. PAPER PREPARED FOR THE AGARD FLIGHT MECHANICS PANEL'S SPECIALIST'S MEETING ON STABILITY AND CONTROL, CAMBRIDGE, SEPT. 1966.

* ABSTRACT *

THE EXPERIENCE GAINED DURING THE USE OF A GROUND BASED FLIGHT SIMULATOR FOR STUDYING THE HANDLING QUALITIES OF FIXED WING AND V.T.O.L. AIRCRAFT IS DISCUSSED. THE PROBLEM OF SIMULATOR VALIDATION IS CONSIDERED, AND EXAMPLES OF COMPARATIVE STUDIES BETWEEN ACTUAL AND SIMULATED FLIGHT ARE GIVEN. EXAMPLES OF SOME RECENT INVESTIGATIONS ARE USED TO ILLUSTRATE THE TYPE OF ORIGINAL RESEARCH STUDIES MADE ON THE SIMULATOR. MORE GENERAL CONCLUSIONS REGARDING THE USE OF SIMULATION FOR HANDLING QUALITIES WORK ARE ALSO GIVEN.

FERRY, D.F. AND BURHAM, J. A FLIGHT SIMULATION STUDY OF DIFFICULTIES IN PILOTING LARGE JET TRANSPORT AIRCRAFT THROUGH SEVERE ATMOSPHERIC DISTURBANCES. 'MINISTRY OF AVIATION, AERONAUTICAL RESEARCH COUNCIL', REPORT C. P. NO. 906, SEPTEMBER 1965, 52 PP, AD 813 961.

* ABSTRACT *

A GROUND BASED FLIGHT SIMULATOR, HAVING MOTION FREEDOMS IN PITCH AND ROLL HAS BEEN USED TO STUDY THE DIFFICULTIES OF FLYING A REPRESENTATIVE JET TRANSPORT AIRCRAFT THROUGH SEVERE STORM TURBULENCE. RANDOM ATMOSPHERIC DISTURBANCES OF RMS VELOCITY 15 FT/SEC. COMBINED WITH LONGER TERM DRAUGHTS IN THE VERTICAL PLANE OF UP TO 200 FT/SEC. WERE STUDIED DURING FLIGHT ON INSTRUMENTS. MOST PILOTS HAD SURPRISINGLY LITTLE DIFFICULTY IN CONTROLLING THE AIRCRAFT DESPITE THE SEVERE CONDITIONS REPRESENTED. SOME WHO MADE POWER AND TRIM CHANGES FREELY, HOWEVER, TENDED TO SET UP LONG PERIOD OSCILLATIONS IN SPEED AND FLIGHT PATH, SIMILAR TO THOSE WHICH HAVE BEEN REPORTED IN FLIGHT. THE RESULTS PROVIDE A USEFUL EXPERIMENTAL DEMONSTRATION OF THE VALIDITY OF CURRENT ROUGH AIR FLYING TECHNIQUES.

FERRY, D.F. AND NAISH, J.M. 'FLIGHT SIMULATION FOR RESEARCH'. JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY, 68: 645-662, 1964.

* ABSTRACT *

CONCLUSIONS OF TWO RESEARCH SCIENTISTS FROM A NUMBER OF YEARS' WORK INVOLVING AIRCRAFT AND SIMULATOR EVALUATIONS OF HANDLING CHARACTERISTICS AND INFORMATION DISPLAYS. NEED FOR MOTION CUES THOUGHT TO VARY WITH AIRCRAFT CHARACTERISTICS BEING SIMULATED. WITH MOTION, PILOTS CAN ACHIEVE STABILITY MORE QUICKLY AND WITH MORE ECONOMIC CONTROL USAGE FOLLOWING A DISTURBANCE. OPINION THAT IT IS MORE IMPORTANT TO ATTEMPT SOME SIMULATION OF ALL RELEVANT ASPECTS THAN TO CONCENTRATE ON PERFECTING ONE (E. G., COCKPIT MOTION).

PERRY, D.F., WARTON, L.F., AND WELBURN, C.E. A FLIGHT SIMULATOR FOR RESEARCH INTO AIRCRAFT HANDLING CHARACTERISTICS. ROYAL AIRCRAFT ESTABLISHMENT, TECHNICAL REPORT NO. 66373, DECEMBER 1966.

* ABSTRACT *

THE TECHNICAL FEATURES OF A PILOTED FLIGHT SIMULATOR, USED IN THE STUDY OF AIRCRAFT HANDLING QUALITIES, ARE DESCRIBED. THE EQUIPMENT INCLUDES AN ANALOGUE COMPUTER, SEVERAL VISUAL SIMULATION SYSTEMS USING BOTH DIRECT OPTICAL AND ELECTRONIC TECHNIQUES, AND HYDRAULICALLY DRIVEN MOTION SYSTEMS FOR PROVIDING THE PILOT WITH ACCELERATION CUES.

SOME COMMENTS ON THE EFFECTIVENESS OF THESE DEVICES FOR SIMULATING PILOTED FLIGHT ARE INCLUDED.

PETERS, R.A. DYNAMICS OF THE VESTIBULAR SYSTEM AND THEIR RELATION TO MOTION PERCEPTION, SPATIAL DISORIENTATION AND ILLUSIONS. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, APRIL 1969, NASA CR-1309.

* ABSTRACT *

IN PILOTING TASKS, VISUAL OBSERVATION OF INSTRUMENT INDICATORS AND OF THE VISUAL FIELD, AND SENSATIONS OF MOTION, PROVIDE THE SENSIBLE SIGNALS UPON WHICH THE PILOT BASES HIS CONTROL OF THE AIRCRAFT. VARIATIONS OF THE GRAVITATIONAL-INERTIAL FORCE ENVIRONMENT DURING THE FLIGHT OF AN AIRCRAFT AFFECT THE PILOT'S MOTION SENSORS IN HIS VESTIBULAR SYSTEM AND THROUGH THEM AFFECT HIS CONTROL OF THE VEHICLE, HIS VISUAL PROCESS, AND HIS SENSE OF ORIENTATION.

THROUGH A REVIEW OF THE LITERATURE, A STUDY IS MADE OF THE BASIC PHYSIOLOGY OF THE HUMAN VESTIBULAR SYSTEM AND ITS INTERCONNECTION WITH THE OCULOMOTOR SYSTEM. THE DYNAMIC FUNCTIONS OF THE SEMICIRCULAR CANALS AND UTRICLES (OTOLITH ORGANS) AND THE RELATION BETWEEN SUBJECTIVE PERCEPTIONS OF MOTION AND THE ACCELERATIONS WHICH PRODUCE THEM ARE STUDIED. MATHEMATICAL

MODELS OF THE DYNAMIC FUNCTIONS OF THE VESTIBULAR SYSTEM ARE PRESENTED.

THE VISUAL AND PERCEPTUAL ILLUSIONS WHICH LEAD TO DISORIENTATION AND WHICH ARE PRODUCED BY MOTION STIMULATION OF THE VESTIBULAR SYSTEM ARE DISCUSSED. THE VARIOUS ILLUSIONS EXPERIENCED BY PILOTS OF AIRCRAFT ARE RELATED TO THE ACCELERATIONS WHICH PRODUCE THEM AND TO THE DYNAMICS OF THE VESTIBULAR SENSORS INVOLVED.

F.R. PETERSON - MOVABLE AND ROTATABLE TOP
PATENT NO. 3,288,421
FILED MARCH 29, 1965 GRANTED NOV. 29, 1966

NO ABSTRACT

PHILLIPS, W.H. AND CHEATHAM, D.C. ABILITY OF PILOTS TO CONTROL SIMULATED SHORT-PERIOD YAWING OSCILLATIONS, NACA RM-L50006, NOVEMBER 13, 1950.

* ABSTRACT *

THE RESULTS OF AN INVESTIGATION OF PILOT'S ABILITY TO CONTROL SHORT-PERIOD YAWING OSCILLATIONS IN A SIMULATING DEVICE ARE PRESENTED. PILOT'S ABILITY TO CONTROL THE SHORT-PERIOD YAWING OSCILLATIONS HAS BEEN DETERMINED AS A FUNCTION OF PERIOD, CONTROL EFFECTIVENESS, AND INHERENT DAMPING OR INSTABILITY.

PHILLIPS, W.H., GUEICH, J.J. AND ADAMS, J.J. LANGLEY RESEARCH CENTER SIMULATION FACILITIES FOR MANNED SPACE MISSIONS. (THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS' ASME PAPER 63-AHGT-91, JAN. 1963.

* ABSTRACT *

SIMULATORS ARE USED EXTENSIVELY AT THE NASA RESEARCH CENTERS TO INVESTIGATE THE PILOTING PROBLEMS OF SPACE VEHICLES. THIS PAPER PRESENTS A DISCUSSION OF THE MISSION UNDER STUDY AND DESCRIBES A NUMBER OF SIMULATORS NOW IN USE OR PLANNED FOR THESE STUDIES AT THE LANGLEY RESEARCH CENTER AND AT OTHER CENTERS. THESE FACILITIES WILL PERMIT AN EXAMINATION OF THE PROBLEMS OF PILOT CONTROL OF EARTH ENTRY, RENDEZVOUS, DOCKING, LUNAR ORBIT ESTABLISHMENT, LUNAR LANDING, LUNAR TAKE-OFF, AND OTHER PHASES OF SPACE MISSIONS. A BRIEF REVIEW OF LANGLEY SIMULATION STUDIES IN THE FIELD OF HUMAN RESPONSE CHARACTERISTICS IS ALSO PRESENTED. (AUTHOR)

PIRANIAN, A.G. THE EFFECT OF THE INDIVIDUAL AND COMBINED STRESSES OF VIBRATION AND SUSTAINED 'G' ON PILOT PERFORMANCE. AGARD CP-145, 1975.

* ABSTRACT *

A CENTRIFUGE, EQUIPPED WITH AN F-4B (PHANTOM) MOVING-BASE COCKPIT WAS USED TO EVALUATE THE INFLUENCES OF SUSTAINED NORMAL ACCELERATIONS, COMBINED VERTICAL AND LATERAL BUFFET LOADS, AND AIRCRAFT FLYING QUALITIES ON AIR-TO-AIR TRACKING PERFORMANCE DURING SIMULATED COMBAT MANEUVERING. ELEVEN TEST PILOTS TRACKED A MOVING TARGET WITH A FIXED RECTICLE, CENTRALLY SITUATED ON THE FRONT WINDSCREEN. AN ALL-ATTITUDE 'OUTSIDE WORLD' VIEW WAS PROVIDED IN COLOR. SUSTAINED NORMAL ACCELERATIONS FROM 1.3 TO 5.0 G, BUFFET EFFECTS UP TO $+ BR = 0.5 G$, AND LATERAL DIRECTIONAL FLYING QUALITIES WERE VARIED INDEPENDENTLY AND IN SEVERAL COMBINATIONS TO ASSESS THEIR INDIVIDUAL AND COMBINED INFLUENCES ON TRACKING PERFORMANCE. THE LATTER WAS MEASURED IN TERMS OF PERCENTAGE TIME DURING WHICH THE TARGET WAS WITHIN PRESCRIBED LIMITS, PROJECTED MISS DISTANCE FROM THE TARGET AND IN CHAFFER-HARPER PILOT OPINION RATINGS.

CONCLUSIONS

1. BUFFET INTENSITIES OF UP TO $+ BR = 0.5 G$ AT A FREQUENCY OF 10 CPS HAVE A NEGLIGIBLE INFLUENCE ON TRACKING PRECISION.
2. SUSTAINED HIGH NORMAL ACCELERATIONS OF UP TO 5.0G APPRECIABLY DEGRADE TRACKING PRECISION.
3. THE INFLUENCE OF AIRCRAFT FLYING QUALITIES WAS THE GREATEST. DECREASED DUTCH ROLL FREQUENCY AND/OR DAMPING, ADVERSE AILERON YAW AND PROVERSE AILERON YAW ALL HAVE DEGRADING EFFECTS ON PERFORMANCE. ABSENCE OF AILERON YAW RESULTED IN OPTIMUM TRACKING.
4. TRACKING PRECISION CAN BEST BE IMPROVED BY (A) MORE PILOT TRAINING UNDER HIGH NORMAL ACCELERATIONS AND (B) IMPROVING AIRCRAFT STABILITY AT HIGH ANGLES OF ATTACK.

FLATNER, L.D. - TRAINING DEVICE

PATENT NO. 2,344,454

FILED DEC. 7, 1942

GRANTED MARCH 14, 1944

NO ABSTRACT

S.M. POOLE, ET AL - FLIGHT SIMULATOR

PATENT NO. 3,269,030

DATE FILED - FEB. 6, 1964 DATE GRANTED - AUG. 30, 1966

NO ABSTRACT

 PEULTER, R.F. AND WILSON, R.V. 'PILOTS ASSESSMENTS OF A PITCH MOTION SYSTEM FOR A FLIGHT SIMULATOR'. ROYAL AIR FORCE INSTITUTE OF AVIATION MEDICINE, SCIENTIFIC MEMORANDUM 82, FEB. 1968.

* ABSTRACT *

THIS REPORT DISCUSSES THE RESULTS OF AN EXERCISE IN WHICH THE SIMULATOR FACILITIES OF THE FLIGHT SKILLS SECTION AT THE INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH, WERE EMPLOYED IN CONJUNCTION WITH THE EMPIRE TEST PILOT'S SCHOOL. THE EXERCISE ITSELF COMPRISED PART OF THE ETFS COURSE, AND WAS SEEN AS AN OPPORTUNITY FOR THE STUDENTS TO WORK IN CLOSE LIAISON WITH ENGINEERS AS PART OF A SMALL RESEARCH TEAM. ONE OF THE MAIN INTENTIONS WAS TO INTRODUCE THE TEST PILOTS TO THE ASSESSMENT OF SIMULATORS, AND TO DEMONSTRATE THEIR USE AS A RESEARCH TOOL.

THE SUBJECTS WERE REQUIRED TO ASSESS THE PITCH MOTION SYSTEM OF THE IAM FLIGHT SIMULATOR USING A GIVEN FLIGHT PLAN (ANNEX 2). A SUBSIDIARY REQUIREMENT WAS THE EVALUATION OF THE FLIGHT PLAN AS AN EFFECTIVE TEST OF THE MOTION SYSTEM'S CAPABILITIES. THE PILOTS HAD AT THEIR DISPOSAL THE IAM FLIGHT SIMULATOR WITH ITS CAPABILITY OF OPERATING EITHER FIXED BASED OR WITH ONE DEGREE OF MOTION (IN PITCH), AND RECORDING FACILITIES. HOW THESE WERE UTILIZED AND HOW THE PROBLEM WAS TACKLED WAS LEFT ENTIRELY TO THE INDIVIDUAL PILOT. THE BRIEFING GIVEN TO THE PILOTS PRIOR TO THE EXERCISE IS SHOWN IN ANNEX 1.

ELEVEN ETFS PILOTS PARTICIPATED IN THE ABOVE EXERCISE AND THEIR REPORTS ASSESSING THE PITCH MOTION SYSTEM WERE MADE AVAILABLE TO IAM FOR ANALYSIS. DIGESTS OF THE ELEVEN REPORTS WERE MADE AND AMALGAMATED (WITH CONCLUSIONS AND COMMENTS) TO FORM THE BASIS OF THIS REPORT.

THE MAIN CONCLUSIONS CONCERNING THE PITCH MOTION SYSTEM WERE: (1) PITCH MOTION WAS USEFUL, AND (2) THE PITCH MOTION SYSTEM COULD BE IMPROVED BY REMOVING THE JERKINESS AND ADDING A RATE TERM IN THE MOTION EQUATION.

 ROVENMIRE, H.K. AND ROSCOE, S.N. 'AN EVALUATION OF GROUND-BASED FLIGHT TRAINERS IN ROUTINE PRIMARY FLIGHT TRAINING'. 'HUMAN FACTORS', 1971, 13(2), 109-116.

* ABSTRACT *

THE RELATIVE BENEFITS OF DIFFERENT TYPES OF FLIGHT TRAINING EQUIPMENT WERE EVALUATED IN A ROUTINE INSTRUCTIONAL SITUATION WITH NO PARTICULAR CONSTRAINTS PLACED UPON THE INSTRUCTOR AS TO HOW HE USED THE EQUIPMENT AND WITHOUT INTERFERING WITH THE NORMAL COURSE OF FLIGHT TRAINING. THE SPECIFIC OBJECTIVES OF THIS RESEARCH PROGRAM WERE (1) TO EVALUATE THE FLIGHT

INSTRUCTORS' ABILITY TO PREDICT SUCCESS IN PRIVATE PILOT TRAINING ON THE BASIS OF STUDENTS' INITIAL PERFORMANCES IN EACH OF TWO GROUND TRAINERS AS OPPOSED TO ACTUAL AIRCRAFT (2) TO DETERMINE THE RELATIVE VALUE OF 11 HOURS OF FLIGHT INSTRUCTION IN TWO DIFFERENT GROUND TRAINERS AND (3) TO DEVELOP AN OBJECTIVE SCALE FOR CHECKING FLIGHT PROFICIENCY. THERE WAS A SIGNIFICANT POSITIVE CORRELATION OF 0.50 BETWEEN PREDICTIONS BASED ON TWO HOURS OF TRAINING IN THE GROUND-BASED TRAINERS AND ACTUAL HOURS REQUIRED TO PASS THE FLIGHT CHECK, BUT A NON-SIGNIFICANT NEGATIVE CORRELATION OF 0.22 FOR PREDICTIONS BASED ON TWO HOURS IN THE AIRCRAFT. THE GROUND TRAINER GROUPS PASSED THEIR FLIGHT CHECKS WITH AN AVERAGE OF SLIGHTLY MORE THAN AN HOUR GREATER TOTAL TIME THAN THOSE TRAINED EXCLUSIVELY IN THE AIRCRAFT. ON THE BASIS OF EQUIVALENT LEVELS OF GROUP PERFORMANCE, 11 HOURS OF TRAINING IN THE AN-T-18 RESULTED IN A SAVING OF 9 HOURS OF FLIGHT TIME, THEREBY YIELDING A TRANSFER EFFECTIVENESS RATIO OF 0.8. ELEVEN HOURS OF TRAINING IN THE CAT-1 RESULTED IN A SAVING OF 11 HOURS OF FLIGHT TIME, YIELDING A TRANSFER EFFECTIVENESS RATIO VALUE OF 1.0. THE TRANSFER EFFECTIVENESS RATIO IS A NEW MEASURE THAT DIRECTLY RELATES THE SAVING IN LEARNING ONE TASK TO THE AMOUNT OF TRAINING ON ANOTHER.

 PRICE, D.R. A STUDY OF THE EFFECT OF PERIPHERAL VISION MOTION CUES ON ROLL AXIS TRACKING, AIR FORCE INSTITUTE OF TECHNOLOGY (AFIT-EN) WRIGHT-PATTERSON AFB, OHIO 45433, MASTERS THESIS, REPORT NO. GE/EE/75-37 DECEMBER 1975.

* ABSTRACT *
 SIX SUBJECTS WERE USED AS CONTROLLERS FOR AN EXPERIMENT IN WHICH COMPENSATORY ROLL AXIS TRACKING WAS PERFORMED WITH AND WITHOUT THE PRESENCE OF PERIPHERAL VISION ACTION CUES. TWO DIFFERENT CONTROLLED PLANT DYNAMICS, OF THE GENERAL FORMS K/S AND K/S SQUARED, WERE SIMULATED ON AN ANALOG COMPUTER. CONTROL WAS COMMANDED VIA A FORCE STICK LOCATED IN A STATIONARY FIGHTER AIRCRAFT COCKPIT MOCKUP. CONTROLLED PLANT ROLL RATE, IN THE FORM OF VERTICALLY MOVING BLACK AND WHITE GRID LINES, WAS DISPLAYED ON TWO 21 INCH TELEVISION SCREENS POSITIONED ON EITHER SIDE OF THE COCKPIT. THE TARGET AIRCRAFT'S MOTION WAS SIMULATED BY A SUM-OF-SINES INPUT FORCING FUNCTION. RMS ERROR SCORES AND TIME HISTORIES WERE RECORDED FOR INDIVIDUAL RUNS. FREQUENCY DOMAIN ANALYSIS AND DATA AVERAGING TECHNIQUES WERE USED TO STUDY AND COMPARE SUBJECT PERFORMANCE.

FINDINGS OF THE EXPERIMENT SHOW THAT FOR marginally stable plants of the general form K/S SQUARED, ROLL AXIS TRACKING IS IMPROVED WHEN PLANT ROLL RATE INFORMATION IS PROVIDED IN THE PERIPHERAL FIELD OF VISION. PERFORMANCE IS NOT SIGNIFICANTLY IMPROVED BY THE DISPLAY WHEN THE CONTROLLED PLANT IS STABLE AND OF THE GENERAL FORM K/S . THE PERIPHERAL DISPLAY IMPROVES PERFORMANCE WITH marginally stable plants by providing

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INSTANTANEOUS PLANT RATE INFORMATION WHICH MUST, OTHERWISE, BE OBTAINED BY COMPUTING DERIVATIVES FROM THE CENTRAL ERROR DISPLAY. THE HUMAN CONTROLLER'S COMPUTATIONAL WORKLOAD IS REDUCED, PERMITTING MORE PRECISE RESPONSE TO ANY ADDITIONAL LEAD COMPENSATION NECESSARY TO PROPERLY FOLLOW THE INPUT SIGNAL.

PROPHET, W.W., CARO, P.W. AND HALL, E.R.
SOME CURRENT ISSUES IN THE DESIGN OF FLIGHT TRAINING DEVICES,
PROFESSIONAL PAPER 5-72 MARCH 1972 HUMRR0. IN 25TH ANNIVERSARY
COMMEMORATIVE TECHNICAL JOURNAL, NAVAL TRAINING DEVICE CENTER,
NOVEMBER 1971.

* ABSTRACT *

THIS PAPER DEVELOPS THE RATIONALE THAT TRAINING EQUIPMENT SHOULD BE SELECTED OR DESIGNED TO FURNISH WHAT THE STUDENT NEEDS TO KNOW AND TO BE ABLE TO DO TO PERFORM SUCCESSFULLY ON THE OPERATIONAL JOB. SEVERAL CONSIDERATIONS RELEVANT TO TRAINING EQUIPMENT DESIGN FROM THE SYSTEMS ENGINEERING STANDPOINT ARE EXAMINED. SUGGESTED DESIGN FEATURES BASED UPON PARTICULAR STUDENT LEARNING NEEDS AND ON STUDENT LEARNING CHARACTERISTICS ARE PRESENTED. TRAINING EQUIPMENT DESIGN FEATURES FOR PARTICULAR CATEGORIES OF TRAINING OBJECTIVES AND FOR LEVELS OF TRAINING (E. G., INITIAL TRAINING OF AVIATORS VS. TRANSITION TRAINING) ARE CONSIDERED. ALSO DISCUSSED IS THE CRITICALITY OF THE SYNTHETIC TRAINING PROGRAM WITH RESPECT TO THE TOTAL TRAINING ENGINEERING PROCESS.

PUTG, J.A. MOTION IN FLIGHT TRAINING: A HUMAN FACTORS VIEW.
NAVAL TRAINING DEVICE CENTER, TECH. RPT. NAVTRADEVEN IH-177,
OCT. 1970.

* ABSTRACT *

AN IN-HOUSE STUDY WAS CONDUCTED TO REVIEW THE STATUS OF SIMULATION TECHNOLOGY AS APPLIED TO TRAINING, WITH EMPHASIS ON HUMAN FACTORS PROBLEMS ENCOUNTERED IN MOTION SIMULATION.

THE EFFECT OF INCORPORATING MOTION IN GROUND-BASED VISUAL SIMULATORS WAS CONSIDERED WITH RESPECT TO ITS INFLUENCE ON TRAINING AND ITS ROLE AS A POSSIBLE INHIBITOR OF SIMULATOR SICKNESS.

THE POSITION OF THE HUMAN FACTORS LABORATORY WAS EXPRESSED ON SEVERAL ASPECTS OF SIMULATION RELATED TO TRAINING TECHNOLOGY.
(AUTHOR)

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FLIG, J.A. 'THE SENSORY INTERACTION OF VISUAL AND MOTION CUES'.
IN J.C. REGAN AND G.V. AMICO (EDS.) 'NAVAL TRAINING DEVICE
CENTER'S 25TH COMMEMORATIVE TECHNICAL JOURNAL'. ORLANDO, FLORIDA
NTDC, NOVEMBER 1971, 55-66.

* ABSTRACT *

EFFECTIVE TRAINING DESIGN REQUIRES THAT THE SIGNIFICANCE OF
CUE INTERACTIONS BE ESTABLISHED. CARE MUST BE TAKEN TO
INCORPORATE INTO THE TRAINING DEVICES NOT ONLY THE CUES
REQUIRED FOR TRAINING SPECIFIC TASKS BUT THE ESSENTIAL
COMBINATIONS OF CUES AS WELL.

THIS PAPER DISCUSSES VISUAL AND MOTION INTERACTION FROM THE
STANDPOINT OF: (1) ILLUSIONS AND SPATIAL DISORIENTATION,
(2) SPATIAL ORIENTATION TRAINING AND (3) SIMULATOR SICKNESS.
(AUTHOR)

GUILLEY, F.C. 'SIMULATION TECHNIQUES FOR THE STUDY OF V/STOL
PROBLEMS'. NORTH ATLANTIC TREATY ORGANIZATION, AGARD-R-99, 1964

* ABSTRACT *

MOTION CUES ADDED TO SIMULATOR ALLOWED EASIER CONTROL OF BANK
AND SIDESLIP DURING INSTRUMENT ILS: STATIC OR DYNAMIC COCKPIT
ALLOWED COMPARABLE PERFORMANCE DURING VISUAL ILS. CAB ROLL
LIMITED TO 70% OF REAL TO REDUCE EFFECT ON PILOT OF UNREALISTIC
SWAY FORCE. ONE PILOT, IN STUDY OF LATERAL POWER AND DAMPING
CHARACTERISTICS, SHOWED GOOD CORRELATION FROM ROLL AND YAW
SIMULATION CONDITION TO FLIGHT BUT POOR CORRELATION FROM ROLL
ONLY SIMULATION CONDITION.

GUILLEY, F.C. AND LAWSON, H.F., JR. SIMULATOR STUDY OF THE
LATERAL-DIRECTIONAL HANDLING QUALITIES OF A LARGE FOUR-PROPEL-
LERED STOL TRANSPORT AIRPLANE. 'NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION', TECHNICAL NOTE D-1773, MAY 1963.

* ABSTRACT *

THE LATERAL AND DIRECTIONAL STABILITY AND CONTROL
CHARACTERISTICS OF A LARGE FOUR-PROPELLERED STOL TRANSPORT
AIRPLANE (THE BOUNDARY-LAYER-CONTROL EQUIPPED NC-130B) HAVE
BEEN STUDIED ON THE LANDING APPROACH SIMULATOR TO DETERMINE
CHANGES IN THE CHARACTERISTICS THAT MIGHT BE REQUIRED TO
ACHIEVE SATISFACTORY LATERAL-DIRECTIONAL HANDLING QUALITIES.
THE STUDY HAS SHOWN THAT THE HANDLING QUALITIES CAN BE IMPROVED
BY INCREASED DIRECTIONAL STABILITY AND DAMPING. A LARGE
INCREASE IN STABILITY IN CONJUNCTION WITH INCREASED YAW RATE
DAMPING GAVE SOME IMPROVEMENT, BUT THE REDUCED DIRECTIONAL
RESPONSE TO RUDDER INPUTS PREVENTED THE CONFIGURATION FROM

BEING RATED SATISFACTORY BY THE EVALUATING PILOTS. A SATISFACTORY CONFIGURATION WAS ACHIEVED BY DOUBLING THE BASIC DIRECTIONAL STABILITY AND INCLUDING A DAMPING TERM WHICH GAVE YAWING MOMENTS PROPORTIONAL TO RATE CHANGE OF SIDESLIP.

RAGLAND, S., CHAMBERS, R.M., CROSBIE, R.J., AND HITCHCOCK, L. SIMULATION AND EFFECTS OF SEVERE TURBULENCE ON JET AIRLINE PILOTS. 'U.S. NAVAL AIR DEVELOPMENT CENTER', JOHNSVILLE, NADC-ML-6411, 1964.

* ABSTRACT *

THE AVIATION MEDICAL ACCELERATION LABORATORY OF THE U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, PENNSYLVANIA, WAS REQUESTED BY THE FEDERAL AVIATION AGENCY, WASHINGTON, D.C., TO UTILIZE THE HUMAN CENTRIFUGE TO INVESTIGATE FACTORS CONTRIBUTING TO COMMERCIAL JET AIRCRAFT CRASHES ASSOCIATED WITH SEVERE AIR TURBULENCE. THE PROBLEM UNDERTAKEN WAS TO DETERMINE (1) WHETHER OR NOT AN ADEQUATE SIMULATION OF THE PHYSICAL EVENTS TAKEN FROM THE FLIGHT RECORDER OF A UNITED AIRLINES BOEING 720-B COULD BE REPRODUCED WITH THE CENTRIFUGE, AND (2) TO DETERMINE IF THERE WERE ANY EFFECTS UPON PILOTS UNDER THESE CIRCUMSTANCES DETRIMENTAL TO THE SAFE CONTROL OF THE AIRCRAFT.

THE FIRST PORTION OF THE PROBLEM WAS SUCCESSFULLY ACCOMPLISHED BY PROGRAMMING ON THE CENTRIFUGE THE ACCELERATION PROFILE IN THE G(Z) AXIS OF CAL 720-B, FLIGHT 746, N7213U, WHICH HAD ENCOUNTERED SEVERE TURBULENCE IN THE CIRRUS PORTION OF A THUNDERSTORM AT 37,500 FEET OVER BINEILL, NEBRASKA, ON JULY 1963. THE EVENTS THAT ENSUED WERE TAKEN FROM A FAIRCHILD FLIGHT RECORDER #1127 INSTALLED ABOARD THE AIRCRAFT. IN THIS CASE THE AIRCRAFT HAD SIMULATED TURBULENCE PRODUCED ACCELERATIONS THAT FLUCTUATED FROM A MAXIMUM OF +3.5G(Z) TO A MAXIMUM OF -2G(Z) AT A RANDOM FREQUENCY AVERAGE OF 1 CPS. THE PILOT AND COPILOT WHO HAD FLOWN THE ACTUAL FLIGHT WERE THE FIRST TO EXPERIENCE THE CENTRIFUGE SIMULATION. THEY PRONOUNCED IT EXCELLENT. SUBSEQUENTLY, EIGHT OTHER AIRLINE PILOTS WERE EXPOSED TO THE SIMULATION AND ADJUDGED IT REALISTIC BASED ON THEIR PERSONAL EXPERIENCES IN TURBULENCE DURING THEIR PILOT CAREERS.

EFFECTS UPON PILOT PERFORMANCE DETRIMENTAL TO SAFE CONTROL OF THE AIRCRAFT ARE THOUGHT TO HAVE BEEN OBSERVED AND RECORDED. ON THE BASIS OF THIS LIMITED PILOT STUDY, IT APPEARS THAT THERE IS A CONSISTENT TENDENCY TO EXPERIENCE A KINESTHETIC ILLUSION WHICH CAUSES THE PILOT TO MAKE INAPPROPRIATE PITCH CONTROL MOVEMENTS. WHEN NEGATIVE G(Z) WAS ENCOUNTERED FOR THE FIRST TIME, AN INITIAL MOVEMENT OF THE YOKE IN THE WRONG DIRECTION WAS THE RULE RATHER THAN THE EXCEPTION. SOME STICK MOVEMENTS THAT WERE THOUGHT TO BE INVOLUNTARY RESULTING FROM JOSTLE WERE MADE, BUT THESE WERE NOT CONSIDERED TO BE OF A MAGNITUDE SUFFICIENT TO HAZARD NORMAL AIRCRAFT CONTROL. THE USE OF A SHOULDER HARNESS AS WELL AS A SECURE LAP BELT MADE CONTROL EASIER AND MADE THE PI.

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LOTS FEEL MORE SECURE PSYCHOLOGICALLY. THERE WAS SOME BLURRING OF THE INSTRUMENTS. HOWEVER, IF THE PILOT CONCENTRATED UPON THE ARTIFICIAL HORIZON, HE COULD MAINTAIN A USEFUL PANEL SCAN. ALL PILOTS FELT THE LEAR 3-INCH FACE MODEL 4003 G, TYPE MM3 ARTIFICIAL HORIZON USED IN THE SIMULATION WAS EASIER TO INTERPRET THAN THE TYPE INSTRUMENT EMPLOYED IN THEIR COMMERCIAL JET AIRCRAFT WHICH MAY BECOME UNREADABLE IN UNUSUAL ATTITUDES. ALTHOUGH THE SIMULATION LASTED ONLY SIX MINUTES IN EACH CASE, IT WAS OBVIOUS THAT THE RATE OF ONSET OF FATIGUE WAS MUCH HIGHER THAN IN NORMAL INSTRUMENT FLYING. DISORIENTATION WAS NOT A PROMINENT FEATURE IN THIS EXPERIMENT AND MOTION SICKNESS DID NOT OCCUR. NO ABNORMAL PHYSIOLOGIC RESPONSES WERE ENCOUNTERED.

THESE DATA STRONGLY SUGGEST THAT BY RESPONDING TO A STRONG KINESTHETIC ILLUSION OF CLIMB OR DIVE AFTER CORRECTING FROM AN UNUSUAL NOSE UP OR NOSE DOWN ATTITUDE PILOTS ARE CREATING EVER INCREASING DEVIATIONS FROM NORMAL FLIGHT PITCH ATTITUDE IN BOTH DIRECTIONS ALTERNATELY, SOMEWHAT ANALOGOUS TO PILOT-INDUCED OSCILLATIONS, UNTIL THE AIRCRAFT STALLS AND FALLS OFF INTO A STEEP DIVE THAT IS DIFFICULT TO RECOGNIZE OR TO RECOVER FROM BECAUSE OF THE LIMITATIONS INHERENT IN THE TYPES OF ARTIFICIAL HORIZONS FREQUENTLY EMPLOYED IN THEIR AIRCRAFT.

 RANDLE, R.J. VIBRATIONS IN HELICOPTERS: TRAINING CONSIDERATIONS, WADC TECHNICAL NOTE 59-61, WRIGHT AIR DEVELOPMENT CENTER, WRIGHT-PATTERSON AFB, OHIO AD 212 314, MARCH 1959.

* ABSTRACT *
 HELICOPTER INSTRUCTOR PILOTS WERE INTERVIEWED INDIVIDUALLY TO ANALYZE IN DETAIL THE ROLE THAT VIBRATIONS PLAY IN PILOTING HELICOPTERS. INFORMATION WAS GATHERED WHICH INDICATED THAT VIBRATIONS ARE UTILIZED AS CLUES IN BOTH NORMAL CONTROL AND THE DETECTION AND DIAGNOSIS OF SYSTEM MALFUNCTIONS. TRAINING CONSIDERATIONS ARE DISCUSSED AND RECOMMENDATIONS MADE FOR A RELATIVELY CROSS SIMULATION OF EACH OF THE SEVERAL CLASSES OF VIBRATIONS IN A PROPOSED HELICOPTER INSTRUMENT TRAINER.

 RAFFERN, R.C. FACTORS SURROUNDING MOTION PLATFORM-VISUAL SYSTEM COUPLING IN FLIGHT SIMULATORS, NAVAL TRAINING EQUIPMENT CENTER TECHNICAL NOTE NAVTRAEQUIPCEN NO. 42, FEBRUARY, 1975. 215

* ABSTRACT *
 SOME OF THE FACTORS AFFECTING THE BEHAVIOR OF MOTION SYSTEMS AND VISUAL SYSTEMS USED SIMULTANEOUSLY ARE CONSIDERED. IN PARTICULAR, THE FLIGHT VISUAL-MOTION COUPLING PROBLEM IS ADDRESSED, WITH RESPECT TO THE NECESSARY ITERATION RATES OF INPUTS, OUTPUTS, AND THE ITERATION RATES OF NUMERICAL COMPUTATIONS. DATA IS PRESENTED FOR SEVERAL OBT/WST HAVING BOTH MOTION AND VISUAL SYS.

TEMS. CONCLUSIONS AND RECOMMENDATIONS ARE DRAWN, BASED UPON THE RESULTS OBTAINED.

A. P. RASMUSSEN ET AL - MULTI- GIMBAL FLIGHT SIMULATOR
PATENT NO. 3,085,354
FILED JAN. 31, 1957 GRANTED APRIL 16, 1963

NO ABSTRACT

RATHERT, G.A. JR. SIMULATION SCIENCES DIVISION, SIMULATOR FACILITIES DESCRIPTION SHEETS. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, AMES RESEARCH CENTER, APRIL 1970

* ABSTRACT *

AMES RESEARCH CENTER HAS FLIGHT SIMULATOR FOR USE IN AERONAUTIC AND SPACE RESEARCH AND DEVELOPMENT EXPERIMENTS. THESE SIMULATORS PROVIDE A MEANS TO EXAMINE BOTH VEHICLE AND CREW FOR POSSIBLE SOLUTIONS TO THE PROBLEMS OF VEHICLE DESIGN, PERFORMANCE, AND OPERATION.

DESCRIPTION SHEETS HAVE BEEN PREPARED WITH BRIEF OUTLINES OF FEATURES AND PERFORMANCE SPECIFICATIONS AND LIMITATIONS. IT MUST BE NOTED THAT MODIFICATIONS ARE BEING MADE CONTINUOUSLY TO THESE DEVICES AND THEIR SPECIFICATIONS ARE SUBJECT TO CHANGE. STAFF PERSONNEL ARE AVAILABLE FOR CONSULTATION TO PROSPECTIVE EXPERIMENTERS TO ASSIST WITH PLANNING AND SCHEDULING OF THEIR EXPERIMENTS.

THESE FACILITIES ARE UNDER THE COGNIZANCE OF THE DIRECTOR OF AERONAUTICS AND FLIGHT MECHANICS.

RATHERT, G.A., JR., CREER, B.Y., DOUVILLIER, J.G., JR. USE OF FLIGHT SIMULATORS FOR PILOT-CONTROL PROBLEMS. INASA MEMORANDUM, 3-6-59 A, WASHINGTON, D.C., 1959.

* ABSTRACT *

COMPARISONS HAVE BEEN MADE BETWEEN ACTUAL FLIGHT RESULTS AND RESULTS OBTAINED WITH FIXED AND MOVING FLIGHT SIMULATORS IN A NUMBER OF PHASES OF FLYING AIRPLANES WITH A WIDE RANGE OF CHARACTERISTICS. THESE RESULTS HAVE BEEN USED TO STUDY THE IMPORTANCE OF PROVIDING MOTION STIMULI IN A SIMULATOR IN ORDER THAT THE PILOT OPERATE THE SIMULATOR IN A REALISTIC MANNER. REGIONS OF AIRPLANE CHARACTERISTICS WHERE MOTION STIMULI ARE EITHER MANDATORY OR DESIRABLE ARE INDICATED.

RATHERT, G.A. JR., CREER, B.Y. AND SADOFF, M. THE USE OF PILOTTED FLIGHT SIMULATORS IN GENERAL RESEARCH. 'ADVISORY GROUP FOR AER. ANALYTICAL RESEARCH AND DEVELOPMENT' (AGARD), NORTH ATLANTIC TREATY ORGANIZATION (NATO) 'REPORT 365', APRIL 1961.

* ABSTRACT *

IN SUMMARY, A NUMBER OF DIRECT CORRELATIONS, BETWEEN FLIGHT AND VARIOUS TYPES OF SIMULATORS HAVE BEEN EXAMINED IN PROBLEM AREAS OF INTEREST FOR RESEARCH ON ADVANCED TRANSPORTS AND MANNED SPACECRAFT. WHERE THE CHARACTERISTICS ARE SUCH THAT THE VEHICLE IS SATISFACTORY OR EASY TO FLY, EVEN THE SIMPLEST FORMS OF SIMULATION ARE EFFECTIVE. THE ADDITION OF MOTION CUES IS REQUIRED IN TWO GENERAL CIRCUMSTANCES:

1. WHERE THE MOTION CUE HELPS THE PILOT BY SUPPLYING A NECESSARY LEAD OR ANTICIPATION CUE, AS IN COPING WITH A LIGHTLY DAMPED OR UNSTABLE VEHICLE OR A SLUGGISH CONTROL SYSTEM.
2. WHERE THE MOTION CUE REALISTICALLY HINDERS THE PILOT IN MAKING A DESIRED CONTROL MOTION, AS IN USING A VERY POWERFUL OR SENSITIVE CONTROL SYSTEM.

A REASONABLE JUDGMENT OF WHETHER SUCH CUES WILL BE NEEDED IN A GIVEN SIMULATION CAN BE MADE BY INSPECTING THE COMPARISONS ON THE DESIGN-CRITERIA CHARTS IN THE REPORTS REFERENCED.

IF LEVELS OF ACCELERATION STRESS GREATER THAN ABOUT 4G ARE ANTICIPATED THEY SHOULD BE INCLUDED IN THE SIMULATION, HOWEVER, THE EXAGGERATED OR SPURIOUS MOTION CUES ENCOUNTERED IN CLOSED-LOOP OPERATION OF A CENTRIFUGE MUST BE TAKEN INTO ACCOUNT.

ADDITIONAL SIMULATION TECHNIQUES, SUCH AS MEASUREMENTS OF PERFORMANCE AND PHYSIOLOGICAL CONDITION AND USE OF THE HUMAN PILOT ANALOG, ARE OFTEN A NECESSARY SUPPLEMENT TO THE SUBJECTIVE OPINION OF THE PILOT.

REASON, J.T. AND ELGIN DIAZ. EFFECTS OF VISUAL REFERENCE ON ADAPTATION TO MOTION SICKNESS AND SUBJECTIVE RESPONSES EVOKED BY GRADED CROSS-COUPLED ANGULAR ACCELERATIONS. 'FIFTH SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE EXPLORATION', HELD AT THE NAVAL AEROSPACE MEDICAL RESEARCH LAB., PENSACOLA, FL., AUG 19-21, 1970. PUBLISHED AS NASA SP-314, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., D.C., 1972.

* ABSTRACT *

THREE GROUPS OF 10 SUBJECTS EACH WERE EXPOSED TO STEPWISE INCREMENTS OF CROSS-COUPLED ANGULAR ACCELERATIONS IN THREE VISUAL MODES: INTERNAL VISUAL REFERENCE (IVR), EXTERNAL VISUAL REFER.

ENCE (EVR), AND VISION ABSENT (VA). THE SUBJECTS IN THE IVR CONDITION REQUIRED SIGNIFICANTLY GREATER AMOUNTS OF STIMULUS EXPOSURE TO NEUTRALIZE THEIR ILLUSORY SUBJECTIVE REACTIONS. THEY ALSO SUFFERED A GREATER LOSS OF WELL-BEING AND A MORE MARKED INCIDENCE OF MOTION SICKNESS THAN DID SUBJECTS IN THE EVR AND VA CONDITIONS.

THE SAME 30 SUBJECTS WERE REEXPOSED TO THE SAME GRADED CROSS-COUPLED STIMULATION 1 WEEK LATER.

THIS TIME, HOWEVER, ALL THE SUBJECTS WERE TESTED UNDER THE IVR CONDITION. ALL THREE GROUPS SHOWED SOME POSITIVE TRANSFER OF ADAPTATION, BUT ONLY THE IVR-IVR COMBINATION REQUIRED SIGNIFICANTLY FEWER HEAD MOTIONS TO ACHIEVE THE SAME LEVEL OF ADAPTATION ON THE SECOND OCCASION. TAKEN OVERALL, HOWEVER, THE MOST EFFICIENT AND LEAST DISTURBING ROUTE TO ADAPTATION AT THE COMPLETION OF THE SECOND TEST WAS VIA THE VA-IVR COMBINATION.

REDIESS, F. A., AND DEETS, D. A.
AN ADVANCED METHOD FOR AIRBORNE SIMULATION.
U. AIRCRAFT, VOL. 1, 4, JUL-AUG 1964.

* ABSTRACT *

A MODEL-CONTROLLED SYSTEM METHOD FOR AIRBORNE SIMULATION THAT OVERCOMES SOME DISADVANTAGES OF PRESENT VARIABLE-STABILITY AIRPLANES HAS BEEN STUDIED ANALYTICALLY AND PROVED FEASIBLE. THIS NEW APPROACH HAS BEEN A NATURAL OUTGROWTH OF THE DEVELOPMENT OF MODEL ADAPTIVE CONTROL SYSTEMS AND USES A SIMILAR MODEL-FOLLOWING CONCEPT. SATISFACTORY MATCHING OF SPECIFIC MOTION PARAMETERS CAN BE OBTAINED FOR MODEL FREQUENCIES AT LEAST UP TO THE NATURAL FREQUENCY OF THE BASE AIRPLANE USED FOR THE AIRBORNE SIMULATOR. TIME HISTORIES FROM ANALOG STUDIES OF A SIMULATOR USING A MODEL-CONTROLLED SYSTEM IN A SMALL SUBSONIC JET TRANSPORT AND USING A HYPOTHETICAL SUPERSONIC TRANSPORT AS THE MODEL ARE PRESENTED AS EXAMPLES OF THE SIMULATION PERFORMANCE EXPECTED. IN A GENERAL DISCUSSION OF AIRBORNE SIMULATION, IT IS OBSERVED THAT THE MOTION OF A SPECIFIC AIRCRAFT CANNOT BE MATCHED COMPLETELY WITH AN AIRBORNE SIMULATOR, EXCEPT AT CERTAIN SPECIFIC CONDITIONS, IF THE NUMBER OF INDEPENDENT CONTROL DEVICES FOR ANGULAR AND LINEAR MOTION IS LESS THAN THE NUMBER OF CORRESPONDING DEGREES OF FREEDOM TO BE SIMULATED. HOWEVER, AIRBORNE SIMULATORS CAN BE VALUABLE RESEARCH AND PILOT-TRAINING TOOLS THROUGH PROPER CHOICE OF THE MOTION PARAMETERS TO BE MATCHED AND BY TAILORING THE PROGRAM TO THE PARTICULAR SIMULATOR USED.

REED, L.E. EFFECTS OF VISUAL-PROPRIOCEPTIVE CLUE CONFLICTS ON HUMAN TRACKING PERFORMANCE. AFHRL-TR-77-32. WRIGHT-PATTERSON AFB, OH: ADVANCED SYSTEMS DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, JUNE 1977.

* ABSTRACT *

OBJECTIVE

THE PURPOSE OF THIS EXPERIMENT WAS TO INVESTIGATE OPERATOR PERFORMANCE IN AN ENVIRONMENT WHICH WAS HIGHLY CONDUCTIVE TO VISUAL-PROPRIOCEPTIVE CONFLICT. THE EXPERIMENTAL TASK REQUIRED THAT SUBJECTS MANEUVER A SIMULATED REMOTELY PILOTTED VEHICLE FROM A SIMULATED AIRBORNE CONTROL STATION (I.E., 'MOTHER SHIP'). THE STATION AND/OR THE VEHICLE WERE GIVEN SUDDEN GUST-LIKE DISTURBANCES (I.E., STIMULI) ON PITCH AND/OR ROLL. SINCE THE VISUAL INPUTS RECEIVED FROM THE VEHICLE WERE INDEPENDENT OF THE MOTION INPUTS FROM THE CONTROL STATION IN THE ENVIRONMENT, IT WAS NECESSARY FOR THE OPERATORS TO DISREGARD SENSATIONS OF MOTION IN ORDER TO MAINTAIN ADEQUATE PERFORMANCE. A MAJOR OBJECTIVE WAS TO COMPARE THE EFFECTS OF CONFLICT AND PRACTICE ON THE PERFORMANCE OF SUBJECTS WHO HAVE HAD VARIOUS LEVELS OF EXPERIENCE WITH MOTION AND TRACKING (I.E., PILOTS, NAVIGATORS, AND INEXPERIENCED SUBJECTS).

APPROACH

IN A BETWEEN GROUPS DESIGN, 48 SUBJECTS REPRESENTING EACH LEVEL OF EXPERIENCE WERE TESTED IN ONE OF FOUR EXPERIMENTAL CONDITIONS: (A) VISUAL ONLY (VO) IN WHICH THE VEHICLE WAS DISTURBED; (B) MOTION ONLY (MO) IN WHICH THE OPERATOR STATION WAS DISTURBED; (C) SINGLE AXIS INCOMPATIBLE (SAI) IN WHICH BOTH WERE DISTURBED, BUT THE VISUAL-MOTION COMBINATIONS WERE IN CONFLICT WITH RESPECT TO DIRECTION; AND (D) SINGLE AXIS COMPATIBLE (SAC) IN WHICH THE VISUAL-MOTION COMBINATIONS WERE COMPATIBLE WITH NORMAL VISUAL CONTACT FLYING. AN ADDITIONAL FOUR PILOTS EXPERIENCED A DOUBLE-AXIS INCOMPATIBLE CONDITION (DAI) IN WHICH THE VISUAL-MOTION COMBINATIONS WERE IN CONFLICT WITH RESPECT TO DIRECTION AND AXIS (E.G., PITCH AND ROLL).

SPECIFICS

THE RESULTS REVEALED THAT THE EXPERIMENTAL CONDITIONS DIFFERED IN THEIR POTENTIAL TO PRODUCE VISUAL-PROPRIOCEPTIVE CONFLICT. THE SAI CONDITION ENGENDERED A HIGH PROPORTION OF REVERSAL ERRORS IN CONTRAST TO VO AND SAC AMONG ALL EXPERIENCE GROUPS. THE DAI CONDITION RESULTED IN A HIGH PROPORTION OF AXIS ERRORS (I.E., STICK DEFLECTIONS COMPENSURATE WITH THE AXIS AND DIRECTION OF MOTION). THE ABSENCE OF MOTION LENGTHENED RESPONSE TIME ON CORRECT RESPONSES, BUT RESULTED IN A LOWER PROPORTION OF ERRORS. THE BEST PERFORMANCE BY ALL GROUPS WAS IN SAC. IT WAS CONCLUDED THAT MOTION PROVIDED CUES THAT ARE NOT EASILY IGNORED. EVIDENCE WAS FOUND TO SUPPORT THE NOTION THAT MOTION PLAYS AN ALERTING FUNCTION AND ALSO PROVIDES INFORMATION ON THE DIRECTION OF ATTITUDE CHANGES.

THE PAST EXPERIENCES OF PILOTS DID NOT HELP THEM OVERCOME THE EFFECTS OF CONFLICT AS MEASURED BY CONTROL ERRORS, BUT IT DID HELP REDUCE THEIR RESPONSE LATENCIES. PILOT RESPONSE TIMES WERE SHORTER THAN THOSE OF NON-PILOTS, BUT THE PROPORTION OF ERRORS MADE BY PILOTS WAS ROUGHLY EQUAL TO THAT OF NON-PILOTS. THE EFFECTS OF PRACTICE WERE EVIDENCED PRIMARILY BY A REDUCTION OF REVERSAL ERRORS IN SAI OVER SESSIONS. THERE WAS NO COMPARABLE

REDUCTION OF AXIS ERRORS BY PILOTS IN DAI.

OVERALL, THERE WAS A GREATER PROPORTION OF CONTROL ERRORS TO ROLL AXIS STIMULI THAN TO PITCH. ALSO, RESPONSE TIMES WERE SHORTER ON PITCH CONTROL AND THE MOVEMENT RATE FOLLOWING THE ONSET OF THE RESPONSE WAS SLOWER ON THAT AXIS THAN ON ROLL. MOREOVER, RESPONSE TIMES TO ERRORS WERE SHORTER AND MOVEMENT RATES SLOWER THAN ON CORRECT RESPONSES.

ANALYSIS OF AMENDMENT TIMES ON ERRORS REVEALED THAT THE SUBJECTS ARRESTED THEIR MOVEMENTS IN LESS THAN THE TIME CLAIMED TO BE NEEDED FOR VISUAL AND KINESTHETIC FEEDBACK. THE RESULTS WERE INTERPRETATED IN TERMS OF ANTICIPATORY BEHAVIOR OCCURRING PRIOR TO THE ONSET OF THE STIMULUS EVENT. WHEN ERRORS OCCUR, THE SUBJECT COMPENSATES FOR THE SHORT RESPONSE TIMES ASSOCIATED WITH ERRORS BY REDUCING MOVEMENT RATE. THIS DECREASE IN MOVEMENT RATE PROVIDES HIM WITH THE TIME NEEDED TO COMPLETE THE PROCESSING OF STIMULUS INFORMATION AND ALLOWS HIM TO HALT THE MOVEMENT SOONER. THIS ACTIVITY CAN OCCUR WITHOUT RECOURSE TO SENSORY FEEDBACK.

REEVES, P.M.
A NON-GAUSSIAN TURBULENCE SIMULATION, TECHNICAL REPORT
AFFDL-TR-69-67, AIR FORCE FLIGHT DYNAMICS LABORATORY, AIR FORCE
SYSTEMS COMMAND, WRIGHT PATTERSON AIR FORCE BASE, OHIO,
DECEMBER 1969.

* ABSTRACT *

A COMPARISON OF THE STATISTICAL PROPERTIES OF LOW ALTITUDE ATMOSPHERIC TURBULENCE AND THE CHARACTERISTICS OF PRESENTLY USED SIMULATION TECHNIQUES SHOWS THAT THESE TECHNIQUES DO NOT SATISFACTORILY ACCOUNT FOR THE NON-GAUSSIAN NATURE OF TURBULENCE. A NON-GAUSSIAN TURBULENCE SIMULATION, INTENDED TO BE USED IN CONJUNCTION WITH PILOTED FLIGHT SIMULATORS, IS DEVELOPED.

THE SIMULATION PRODUCES THREE SIMULTANEOUS RANDOM PROCESSES WHICH REPRESENT THE THREE ORTHOGONAL GUST COMPONENTS. THE PROBABILITY DISTRIBUTION OF EACH COMPONENT IS CHARACTERIZED BY THE MODIFIED BESSEL FUNCTION OF THE SECOND KIND OF ORDER ZERO, K_0 , AND THE POWER SPECTRAL DENSITIES SUGGESTED BY H. L. DRYDEN ARE USED IN A SLIGHTLY MODIFIED FORM. THE RMS INTENSITY AND SCALE LENGTH OF EACH COMPONENT ARE INDEPENDENT PARAMETERS. A GENERAL METHOD OF INTRODUCING CROSS SPECTRA BETWEEN COMPONENTS IS DEMONSTRATED.

THE MULTIPLICATION OF INDEPENDENT RANDOM PROCESSES IS USED TO GENERATE EACH OF THE GUST COMPONENTS. GAUSSIAN WHITE NOISE GENERATORS, ANALOG MULTIPLIERS, AND LINEAR FILTERS ARE USED THROUGHOUT THE SIMULATION. A COMPLETE ANALOG CIRCUIT DIAGRAM IS PRESENTED.

 REEVES, P. M., ET AL.
 DEVELOPMENT AND APPLICATION OF A NON GAUSSIAN ATMOSPHERE
 TURBULENCE MODEL FOR USE IN FLIGHT SIMULATORS
 NASA CR 2451, SEPTEMBER 1974

* ABSTRACT *
 A METHOD IS DESCRIBED FOR GENERATING TIME HISTORIES WHICH MODELS
 THE FREQUENCY CONTENT AND CERTAIN NON-GAUSSIAN PROBABILITY
 CHARACTERISTICS OF ATMOSPHERIC TURBULENCE. THE METHOD ALSO RE-
 PRODUCES THE LARGE GUSTS AND 'PATCHY' NATURE OF TURBULENCE.
 METHODS FOR PRODUCING SUCH TIME HISTORIES USING EITHER ANALOG OR
 DIGITAL COMPUTATION ARE DESCRIBED.

AN EXPERIMENT WAS PERFORMED IN WHICH A STOL AIRPLANE WAS PRO-
 GRAMMED INTO A 6-DEGREE-OF-FREEDOM FLIGHT SIMULATOR AT NASA
 AMES, AND TURBULENCE TIME HISTORIES FROM SEVERAL ATMOSPHERIC
 TURBULENCE MODELS, INCLUDING THE NON-GAUSSIAN MODEL, WERE INTRO-
 DUCED. THE PILOTS' REACTIONS TO THE VARIOUS MODELS ARE
 DESCRIBED.

 REYNOLDS, F.A., SCHELHORN, A.E. AND WASSERMAN, R. DRIVE LOGIC
 FOR IN-FLIGHT SIMULATORS, AIAA PAPER 73-933, AIAA VISUAL AND
 MOTION SIMULATION CONFERENCE, PALO ALTO, CA., SEPT. 1973.

* ABSTRACT *
 VARIABLE STABILITY AIRCRAFT HAVE BEEN IMPROVED TO THE POINT
 WHERE THEY CAN BE CALLED IN FLIGHT SIMULATORS. ONE OF THE IM-
 PROVEMENTS HAS BEEN INDEPENDENT CONTROL OF ALL SIX DEGREES OF
 FREEDOM. THE FOUR CONVENTIONAL CONTROLS HAVE BEEN AUGMENTED BY
 DIRECT LIFT AND DIRECT SIDE FORCE CONTROL. WITHIN THE CAPABIL-
 ITIES OF THESE SIX CONTROLLERS AND THE AIRCRAFT STRUCTURE, THE
 CREW STATION IN THE AIRCRAFT OCCUPIED BY THE EVALUATION PILOT
 CAN BE MOVED IN THE DESIRED MANNER. THIS PAPER DESCRIBES CON-
 VENIENT COMPUTATION AND IMPLEMENTATION TECHNIQUES WHICH HAVE
 BEEN DEVISED TO PRODUCE THE DESIRED DYNAMIC MOTION, GROUND
 EFFECTS, APPARENT CROSSWIND, AND OTHER SPECIAL EFFECTS.

 G.L. RICARD, M.L. CYRUS, CAPTAIN D.C. COX, T.K. TEMPLETON, L.C.
 THOMPSON
 COMPENSATION FOR TRANSPORT DELAYS PRODUCED BY COMPUTER IMAGE
 GENERATION SYSTEMS, NAVAL TRAINING EQUIPMENT CENTER, ORLANDO, FL
 AND FLYING TRAINING DIV., AFHRL, WILLIAMS AFB, ARIZONA, NAVTRA-
 EGUIPCEN IH-297/AFHRL-TR-78-46, JUN 1978.

* ABSTRACT *

THIS REPORT DESCRIBES A COOPERATIVE NAVY/AIR FORCE EFFORT AIMED AT THE PROBLEM OF IMAGE-FLUTTER ENCOUNTERED WHEN VISUAL DISPLAYS THAT PRESENT COMPUTER-GENERATED IMAGES ARE USED FOR THE SIMULATION OF CERTAIN FLYING SITUATIONS. TWO EXPERIMENTS ARE DESCRIBED THAT EXTEND LABORATORY WORK ON DELAY COMPENSATION SCHEMES TO THE SIMULATION OF FORMATION FLIGHT IN A RESEARCH DEVICE -- THE ADVANCED SIMULATOR FOR PILOT TRAINING. THE SCHEME USED WAS ONE WHERE LOW-PASS FILTERS WERE ADDED TO THE LEAD-GENERATION SOFTWARE OF THE VISUAL DISPLAY SYSTEM. BOTH STUDIES WERE GEARED TO DETERMINE BREAK-POINTS FOR THOSE FILTERS THAT WOULD ALLOW ADEQUATE FLYING CONTROL PERFORMANCE AND PROVIDE AN ACCEPTABLE DISPLAY. THESE EXPERIMENTS WERE BASED ON THE NOTION THAT A TRADE EXISTS BETWEEN THE SUPPRESSION OF THE VISUAL IMAGE'S FLUTTER AND THE REMOVAL OF THE LOW FREQUENCY INFORMATION NECESSARY FOR FLIGHT CONTROL. ONE EXPERIMENT REPRESENTED A FACTORIAL COMBINATION OF SETTINGS OF THE DISPLAY FILTERS AND THE NON-VISUAL CUES OF AIRCRAFT MOTION PROVIDED BY THE ASPT'S G-SEAT AND MOTION PLATFORM, AND THE SECOND REPRESENTED A SIMPLE COMPARISON OF FILTER SETTINGS. BOTH STUDIES INDICATED THAT, AT LEAST FOR FORMATION FLIGHT, THERE IS A RANGE OF FILTER SETTINGS WHICH WILL NOT ADVERSELY AFFECT FLIGHT CONTROL AND WILL ADEQUATELY SUPPRESS VISUAL FLUTTER. THIS RANGE REPRESENTS HALF-POWER SETTINGS FOR THE FILTERS OF 3/4 TO 1 HERTZ.

RICARD, G.L. AND PUIG, J.A. DELAY OF VISUAL FEEDBACK IN AIRCRAFT SIMULATORS. NAVAL TRAINING EQUIPMENT CENTER, ORLANDO, FLORIDA, TECH. NOTE: NAVTRAEGUIPCEN TN-561, MARCH 1977.

* ABSTRACT *

THE LITERATURE OF THE MANUAL CONTROL OF SYSTEMS INCORPORATING DELAYS IN THE PRESENTATION OF VISUAL INFORMATION IS REVIEWED FOR THE DEVELOPMENT OF SPECIFICATIONS OF VISUAL DISPLAYS FOR FLIGHT SIMULATORS. SEVERAL CASES ARE PRESENTED WHERE DISPLAY DELAYS HAVE AFFECTED THE USE OF OPERATIONAL SIMULATION DEVICES, AND THE MEANS CURRENTLY USED TO CONTEND WITH THOSE DELAYS ARE DISCUSSED. TWO APPROACHES TO PREPARING SPECIFICATIONS ARE OFFERED AND AVAILABLE INFORMATION RELEVANT TO EACH IS PRESENTED.

THE NEED EXISTS TO DEFINE MORE PRECISELY THE LIMITS FOR TIME DELAYS, ESPECIALLY FOR FLIGHT SIMULATORS, AS THESE LIMITS CAN AFFECT THE DESIGN OF VISUAL DISPLAYS, OF 'MOTION BASES' (INCLUDING SEAT CUSHION DYNAMICS), OR OF ANY SENSOR DISPLAY THAT REQUIRES DYNAMIC INTERACTION OF CREW MEMBERS WITH THE SYSTEM.

RICHARDSON, J.D. AND A'HARRAH, R.C. THE APPLICATION OF FLIGHT SIMULATORS TO THE DEVELOPMENT OF THE A-5A VIGILANTE. NORTH AMERICAN AVIATION, INC., COLUMBUS DIVISION. PRESENTED AT 'AIAA

SIMULATION FOR AEROSPACE FLIGHT, NATIONAL SPECIALIST MEETING,
COLUMBUS, OHIO, AUG 26-28, 1963.

* ABSTRACT *

IN 1955, THE COLUMBUS DIVISION OF NORTH AMERICAN AVIATION STARTED DEVELOPMENT OF THE A-5A VIGILANTE. THIS ALL WEATHER WEAPON SYSTEM REPRESENTED AN APPRECIABLE ADVANCE IN THE STATE-OF-THE-ART OF AIRCRAFT DESIGN, PARTICULARLY IN THE AREA OF OBTAINING A REASONABLE COMPROMISE BETWEEN THE CONFLICTING REQUIREMENTS FOR SUSTAINED SUPERSONIC FLIGHT AND GOOD LOW-SPEED CHARACTERISTICS NEEDED FOR CARRIER OPERATION. THIS PAPER BRIEFLY TRACES THE DEVELOPMENT OF THE A-5A, AND IN PARALLEL, THE DEVELOPMENT AND USE OF FLIGHT SIMULATORS AS AN AID TO SOLVING MANY OF THE CRITICAL DEVELOPMENT PROBLEMS ENCOUNTERED. THE DISCUSSION WILL BE PRIMARILY CONCERNED WITH THE USE OF SIMULATION FOR THE SOLUTION OF HANDLING QUALITIES AND FLIGHT CONTROL PROBLEMS.

THE INFLUENCES OF SIMULATION PROGRAMS WHETHER PILOTED OR NON-PILOTED WHICH WERE PERTINENT TO THE A-5A DESIGN ARE DISCUSSED. A COMPARISON OF SIMULATOR RESULTS AND FLIGHT TEST DATA IS MADE TO PROVIDE PROOF OF THE VALIDITY OF THE SIMULATOR AS A DESIGN TOOL. PILOT EVALUATION OF THE AIRPLANE CHARACTERISTICS FOR THE FIXED AND MOVING BASE SIMULATOR STUDIES IS PRESENTED IN TERMS OF ISOPERFORMANCE BOUNDARIES AND PILOT RATINGS OF THE FUNDAMENTAL DYNAMIC CHARACTERISTICS IN ORDER THAT THE READER CAN READILY INTERPRET THE DATA AND COMPARE WITH OTHER AIRCRAFT WITH WHICH HE IS FAMILIAR.

FINALLY, RECOMMENDATIONS ARE MADE REGARDING THE UTILIZATION OF PILOTED FLIGHT SIMULATORS IN AIDING THE DEVELOPMENT OF FUTURE ADVANCED AIRCRAFT CONCEPTS. IT SHOULD BE NOTED THAT THESE RECOMMENDATIONS REPRESENT THE OPINIONS OF THE AUTHORS AND ARE NOT NECESSARILY THOSE OF NORTH AMERICAN AVIATION, INC.
(AUTHOR)

D.F. RICHTER, ET AL - SIX DEGREE OF FREEDOM APPARATUS
PATENT NO. 3,449,843
FILED AUG. 3, 1966 GRANTED JUNE 17, 1969

NO ABSTRACT

RINGLAND, R.F., STAPLEFORD, R.L. AND MAGDALENO, R.E., MOTION EFFECTS ON AN IFR HOVERING TASK - ANALYTICAL PREDICTIONS AND EXPERIMENTAL RESULTS. NASA CR-1933 SYSTEMS TECHNOLOGY, INC., 13766 SOUTH HAWTHORNE BOULEVARD, HAWTHORNE, CALIFORNIA FOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C. NOV. 1971.

AD-A061 687

NAVAL TRAINING EQUIPMENT CENTER ORLANDO FLA
MOTION IN FLIGHT SIMULATION: AN ANNOTATED BIBLIOGRAPHY. (U)
JUL 78 J A PUIG, W T HARRIS, & L RICARD
NAVTRAEQUIPC-IH-298

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* ABSTRACT *

AN ANALYTICAL PILOT MODEL INCORPORATING THE EFFECTS OF MOTION CUES AND DISPLAY SCANNING AND SAMPLING IS TESTED BY COMPARING PREDICTIONS AGAINST EXPERIMENTAL RESULTS ON A MOVING BASE SIMULATOR. THE SIMULATED TASK IS THAT OF PRECISION HOVERING OF A VTOL HAVING VARYING AMOUNTS OF RATE DAMPING, AND USING SEPARATED INSTRUMENT DISPLAYS. MOTION CUE EFFECTS ARE INVESTIGATED BY RUNNING THE EXPERIMENT UNDER FIXED AND MOVING BASE CONDITIONS. THE LATTER IN TWO MODES -- FULL MOTION, AND ANGULAR MOTION ONLY. DISPLAY SCANNING BEHAVIOR IS MEASURED ON SOME OF THE RUNS.

THE RESULTS OF THE PROGRAM SHOW THAT PERFORMANCE IS BEST WITH ANGULAR MOTION ONLY, MOST PROBABLY BECAUSE OF A G-VECTOR TILT CUE IS AVAILABLE TO THE PILOT IN THIS MOTION CONDITION. THIS PROVIDES AN ATTITUDE INDICATION EVEN WHEN NOT VISUALLY FIXATING THE ATTITUDE DISPLAY. VESTIBULAR THRESHOLD EFFECTS ARE ALSO PRESENT IN THE RESULTS BECAUSE OF THE DISPLAY SCALING USED TO PERMIT HOVERING POSITION CONTROL WITHIN THE MOTION SIMULATOR LIMITS. NO WASHOUTS ARE USED IN THE SIMULATOR DRIVE SIGNALS. THE IFR NATURE OF THE TASK RESULTS IN LARGE DECREMENTS IN PILOT OPINION AND PERFORMANCE RELATIVE TO VFR CONDITIONS BECAUSE OF THE SCANNING WORKLOAD. MEASUREMENTS OF SCANNING BEHAVIOR ARE SENSITIVE TO MOTION CONDITIONS AND SHOW MORE ATTENTION TO ATTITUDE CONTROL UNDER FIXED BASE CONDITIONS.

RIPLEY, R. AN ASSESSMENT OF THE FLIGHT SIMULATOR MOTION REQUIREMENT. A BRIEF PRESENTED BY COLONEL ROY RIPLEY, CHAIRMAN OF USAF SIMULATOR PANEL, AT THE AIR FORCE HUMAN RESOURCE LABORATORY, WILLIAMS AFB, ARIZONA, 27 JAN 1977.

* ABSTRACT *

SUMMARY: THE SIMULATOR PANEL REVIEWED A NUMBER OF RESEARCH STUDIES WITH THE ASSISTANCE OF THREE EMINENT SCIENTISTS IN THE TRAINING RESEARCH FIELD (DRS. CONRAD KRAFT, PAUL CARO, AND GUY MATHENY). THE PANEL ALSO REVIEWED RECOMMENDATIONS MADE TO THE TACTICAL AIR COMMAND (TAC) BY TWO MEMBERS OF THE SIMULATOR ADVISORY BOARD (SAB) ON THIS ISSUE. THE MAJOR OPERATING COMMANDS, AFSC AND THE NAVY PROVIDED THEIR POSITIONS. CURRENT MOTION TECHNOLOGY AND PLANNED RESEARCH WERE REVIEWED AND THE COST OF ACQUIRING AND OPERATING THE PROGRAMMED MOTIONS SYSTEMS WAS ASSESSED.

RIPLEY, ROY
CHIEF OF NAVAL EDUCATION AND TRAINING LIAISON OFFICE, AIR FORCE HUMAN RESOURCE LABORATORY, FLYING TRAINING DIVISION, WILLIAMS AFB, ARIZONA. USAF ASSESSMENT OF THE FLIGHT SIMULATOR MOTION REQUIREMENT, WITH AN ENCLOSURE (AN ASSESSMENT OF THE FLIGHT SIM.

PLATFORM MOTION REQUIREMENTS: A BRIEF GIVEN BY COLONEL ROY RIPLEY,
CHAIRMAN OF USAF SIMULATOR PANEL, JANUARY 1977.

* ABSTRACT *

THE BRIEF STATES THAT THERE ARE CERTAIN AREAS WHERE THE USAF
STILL HAS DECISION OPPORTUNITY ON PURCHASE OF PLATFORM MOTION
AND IT APPEARS THAT THEIR CONTRACTS ARE GEARED TO ADDING PLAT-
FORM MOTION FOR FUTURE PROCUREMENTS. HOWEVER, GENERAL SCHRUPP,
DEPUTY DIRECTOR OF OPERATIONS AND READINESS, HEADQUARTERS USAF,
AND ALSO SPECIAL ASSISTANT FOR AIRCREW SIMULATORS, INDICATED IN
A DISCUSSION HERE AT NRL/FT ON 10 JAN 1977, THAT THE DECISION
HAD BEEN MADE TO EQUIP ALL HEAVY AIRCRAFT (B-52/KC135/C130) AND
ALL WIDE BODY AIRCRAFT SIMULATORS WITH A MOTION BASE. HE
FURTHER STATED THAT ALL FIGHTERS WOULD NOT BE SO EQUIPPED AND
THAT THE DECISION WOULD BE REVIEWED IN ABOUT A YEAR, AT WHICH
TIME HE EXPECTED NO CHANGE.

RIVERS, H. A., VAN ARSDALL, R. S.
SIMULATOR COMPARATIVE EVALUATION.
IN PROCEEDINGS OF THE 10TH NTEC/INDUSTRY CONFERENCE
TECH. REPT. IH-294,
NOVEMBER 15-17, 1977.

* ABSTRACT *

THE PURPOSE OF THIS PROJECT WAS TO SUBJECTIVELY EVALUATE THE
CAPABILITIES AND LIMITATIONS OF CURRENT FIGHTER CONFIGURED
SIMULATORS TO IDENTIFY FEATURES THAT COULD ENHANCE FUTURE
AIR TO SURFACE SIMULATORS. IN ADDITION, NON-FIGHTER CONFIGURED
OPERATIONAL DEVICES AND CERTAIN SYSTEMS IN DEVELOPMENT WERE
EXAMINED FOR FEATURES HAVING POTENTIAL APPLICATION TO TACTICAL
SIMULATORS.

ROBERTS, D.D., FLORISSANT, AND FENG, C.L.
CONDUCTRON CORP.
CONTROL SYSTEM FOR PLATFORM HAVING SIX DEGREES OF FREEDOM
PATENT NO. 3,529,354, SEPT. 22, 1970.

* ABSTRACT *

THE PLATFORM OF A MOTION BASE IS SUPPORTED BY THREE ELEMENTS
WHICH ACT UPON A POINT ADJACENT ONE SIDE OF THAT PLATFORM AND BY
THREE FURTHER ELEMENTS WHICH ACT UPON A SECOND POINT ADJACENT
THE OPPOSITE SIDE OF THAT PLATFORM, AND EACH OF THOSE POINTS CAN
BE MOVED IN THE X Y AND Z DIRECTIONS, AND THAT PLATFORM CAN BE
ROTATED ABOUT AN AXIS EXTENDING BETWEEN THOSE POINTS, TO
PROVIDE SIX DEGREES OF MOTION FOR THAT PLATFORM.

ROLFE, J.M. 'VEHICLE SIMULATION FOR TRAINING AND RESEARCH'. FARNBOROUGH, ENGLAND: RAF INSTITUTE OF AVIATION MEDICINE, IAM-R-442, MARCH 1968. U77-651 (PROCEEDINGS OF A SYMPOSIUM HELD AT THE UNIVERSITY OF SUSSEX AS PART OF THE 1968 ANNUAL CONFERENCE OF THE ERGONOMICS SOCIETY.)

* ABSTRACT *

VEHICLE SIMULATION MAY BE SUB-DIVIDED CONVENIENTLY INTO TWO ASPECTS - SIMULATION FOR TRAINING, AND SIMULATION FOR RESEARCH. IT IS RARE FOR A SIMULATOR TO BE DESIGNED TO DO BOTH THESE JOBS; RARER STILL FOR IT TO DO THEM SUCCESSFULLY. THE REQUIREMENTS FOR THE TWO TYPES DIFFER CONSIDERABLY, AS DOES THE MANNER IN WHICH THEY ARE OPERATED.

THIS SYMPOSIUM ACKNOWLEDGES TRAINING/RESEARCH DICHOTOMY. THE FIRST THREE PAPERS DEAL WITH TRAINING USING SIMULATORS, AND THE SECOND THREE DISCUSS RESEARCH WITH SIMULATORS. (FROM INTRODUCTORY REMARKS BY A.G. BARNES, BRITISH AIRCRAFT CORP., PRESTON.)

ROLFE, J.M. 'FLIGHT SIMULATOR RESEARCH AT THE ROYAL AIR FORCE INSTITUTE OF AVIATION MEDICINE'. RAF INSTITUTE OF AVIATION MEDICINE. IN 'APPLIED ERGONOMICS', VOL. 4, NO 2, PP 84-90, 1973.

* ABSTRACT *

AFTER TRACING THE DEVELOPMENT OF FLIGHT SIMULATORS, THE AUTHOR REFERS TO THE SIMULATORS USED FOR RESEARCH AT THE RAF INSTITUTE OF AVIATION MEDICINE, DESCRIBING SEVEN EXAMPLES OF THE INSTITUTE'S RESEARCH CARRIED OUT WITH THEIR AID. THESE COVER A COMPARISON OF ATTITUDE INDICATORS, PILOT RESPONSE, MOTION CUES AND LANDING PERFORMANCE, STUDENT PILOTS ASSESSMENTS, FAMILIARIZATION BEHAVIOR, EVALUATING AN AIRBORNE NAVIGATION DISPLAY, AND ATTITUDE AND OPINION SURVEYS.

ROLFE, J.M. KEEPING UP ON THE GROUND - FLIGHT SIMULATORS. RAF, TRAINING COMMAND, BRAMPTON, CUMB., ENGLAND, 'AERONAUTICAL JOURNAL', VOL. 81, JULY 1977, 281-292.

* ABSTRACT *

THE FACTORS INFLUENCING THE VALUE OF FLIGHT SIMULATORS ARE DISCUSSED IN TERMS OF COST EFFECTIVENESS AND THE DEVELOPMENT PROCEDURES FOR A SUSTAINED, EFFECTIVE TRAINING PROGRAM. THE MAJOR PROBLEMS OF SIMULATOR FIDELITY ARE DESCRIBED, INCLUDING (1) THE AMOUNT OF MOTION NECESSARY TO MAKE THE SIMULATOR EFFECTIVE, (2) DIFFICULTIES IN REPRESENTING THE EXTERNAL VISUAL WORLD (WITH THE DESCRIPTIONS OF SEVERAL EXISTING TECHNIQUES ADDED), AND (3) SIMULATION OF OTHER TRAFFIC SIMULATORS ARE IDENTIFIED, SUCH AS

COST, RISK, ECOLOGICAL CONSIDERATIONS, TRAINING AND COST EFFECTIVENESS, SAFETY, AND TECHNOLOGICAL FEASIBILITY. A BASIC TRAINING PROGRAM IS OUTLINED WITH REFERENCE TO AIDS AND EQUIPMENT (WALL CHARTS, SLIDES, MOTION PICTURES, ETC.), AND THE EVALUATION OF SUCH A PROGRAM (DEFINING OBJECTIVES, PLANNING AND STAFF SELECTION, AND VALIDATION OF TRAINING PROCEDURES).

 ROLFE, J.M., HAMMERTON-FRASER, A.M., POULTER, R.F. AND SMITH, F.M.B. 'PILOT RESPONSE IN FLIGHT AND SIMULATED FLIGHT'. ROYAL AIR FORCE INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH, HANTS. IN 'ERGONOMICS', 1970, VOLUME 13, NO. 6, 761-768.

* ABSTRACT *

THIS PAPER DESCRIBES AN EXPERIMENT IN WHICH AN ATTEMPT WAS MADE TO ASSESS THE VALUE OF TWO TYPES OF RESPONSE, CONTROL ACTIVITY AND PHYSIOLOGICAL ACTIVITY, AS INDICATIONS OF THE EFFECT ON SIMULATOR FIDELITY OF ADDING PITCH MOTION CUES. THE INVESTIGATION USED A GENERAL PURPOSE RESEARCH SIMULATOR AND A TWO-SEATER HUNTER T7 AIRCRAFT. THE RESPONSES OF NINE EXPERIENCED PILOTS WERE COMPARED WHEN, FLYING ON INSTRUMENTS, THEY UNDERTOOK THE SAME FLIGHT PLAN UNDER THREE DIFFERENT CONDITIONS, NAMELY:

FLIGHT IN THE HUNTER T7 AIRCRAFT;
 SIMULATED FLIGHT IN THE SIMULATOR WITH PITCH MOTION PRESENT,
 AND
 SIMULATED FLIGHT IN THE SAME SIMULATOR WITHOUT MOTION.

 REPELEWSKI, R.R. SIMULATOR REFINES FIGHTER DESIGN. 'AVIATION WEEK & SPACE TECHNOLOGY', MAY 8, 1972

* ABSTRACT *

THIS ARTICLE DESCRIBES NORTHROP'S LARGE-AMPLITUDE SIMULATOR AND SOME OF THE ENGINEER'S AND PILOT OPINION OF ITS CAPABILITIES.

 BROCKE, S.N. INCREMENTAL TRANSFER AND COST EFFECTIVENESS OF FLIGHT TRAINING SIMULATORS. INTEC, INDUSTRY CONFERENCE PROCEEDINGS, NAVTRAEGUIPCEN IH-240, 19-21 NOV. 1974.

* ABSTRACT *

FOR THE CONFERENCE TOPIC: 'TRAINING ECONOMY THROUGH SIMULATION', THE AUTHOR REVIEWED THE KEY ISSUES IN TRANSFER AND COST EFFECTIVENESS OF FLIGHT TRAINING SIMULATORS. HE ALSO REVIEWED KOPRICE (1974) STUDY WHICH HE REFERRED TO AS 'THE FIRST EXPERIMENT BEARING DIRECTLY UPON THE TRANSFER FROM A SIMULATOR TO AN AIRPLANE AS A FUNCTION OF THE KIND OF SIMULATOR MOTION...'. DR.

ROSCBE ALSO BRIEFLY DESCRIBED A TRANSFER EXPERIMENT CONDUCTED AT THE UNIVERSITY OF ILLINOIS USING A LINK GAT-2 GENERAL AVIATION TRAINER TO A LIGHT GENERAL AVIATION AIRCRAFT. THIS EXPERIMENT IS DESCRIBED FULLY IN JACOBS AND ROSCBE (1975).

ROSCBE, S.N. 'EFFECTIVE AND ECONOMICAL SIMULATION IN THE DESIGN AND USE OF AERO SYSTEMS'. SAVOY AVIATION RESEARCH LAB AT THE UNIVERSITY OF ILLINOIS, URBANA-CHAMPAIGN FOR AFOSR, REPORT NO. ARL-75-8/AFOSR-75-3 APRIL 1975. AD NO. A012-012.

* ABSTRACT *

THIS PAPER IS A LIGHTLY EDITED TRANSCRIPT OF A 1975 TALK PRESENTED AT A CONFERENCE ON SIMULATION OF AERO SYSTEMS CO-SPONSORED BY THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH AND THE AIR FORCE FLIGHT DYNAMICS LABORATORY. THE CHARACTERISTICS OF AIRCRAFT SIMULATORS LEADING TO THEIR EFFECTIVE AND ECONOMICAL USE ARE SHOWN EXPERIMENTALLY TO DIFFER AS A FUNCTION OF THEIR APPLICATION, WHETHER IN ENGINEERING RESEARCH, PILOT PERFORMANCE ASSESSMENT AND PREDICTION OR TRAINING. ISSUES IN THE DESIGN AND USE OF FLIGHT TRAINING, SIMULATORS INVOLVE THE EFFECTIVENESS AND ECONOMICS OF MOTION SYSTEMS, VISUAL SYSTEMS, AND PERFORMANCE MEASUREMENT SYSTEMS.

ROSCBE, S.N. AND WILLIGES, R.C. 'MOTION RELATIONSHIPS IN AIRCRAFT ATTITUDE AND GUIDANCE DISPLAYS: A FLIGHT EXPERIMENT'. 'HUMAN FACTORS', 1975, 17, 374-387.

* ABSTRACT *

SIXTEEN NONPILOT NAVAL ROTC STUDENTS WERE TESTED ON TASKS INVOLVING CONFLICTING VISUAL AND VESTIBULAR CUES WHICH FLYING WITH EACH OF FOUR BASIC AIRCRAFT ATTITUDE PRESENTATIONS (MOVING HORIZON, MOVING AIRPLANE, FREQUENCY SEPARATED, AND KINALOG) IN A BEECHCRAFT C-45 AIRPLANE. FLIGHT-DIRECTOR VERSIONS OF EACH DISPLAY PRESENTING EITHER COMPENSATORY OR PURSUIT STEERING GUIDANCE WERE ALSO COMPARED ON A COMMAND FLIGHT PATH TRACKING TASK INVOLVING RANDOM HEADING CHANGES. FOR ALL ATTITUDE PRESENTATIONS, PURSUIT TRACKING WAS SUPERIOR TO COMPENSATORY TRACKING AND THE ORDER OF MERIT OF THE FOUR ATTITUDE PRESENTATIONS IN FLIGHT CASTS DOUBT UPON THE VALIDITY OF PREVIOUS SIMULATOR EXPERIMENTS. IT WAS CONCLUDED THAT THE PRINCIPLE OF DISPLAY FREQUENCY SEPARATION PROVIDES AT LEAST EQUIVALENT PILOT STEERING PERFORMANCE TO THAT OBTAINED WITH THE CONVENTIONAL MOVING HORIZON FORMAT, WHILE THE ANTICIPATORY CUES IT AFFORDS TENDS TO REDUCE THE INCIDENCE OF CONTROL REVERSALS UNDER CIRCUMSTANCES OF SUBLIMINAL ANGULAR ACCELERATION BY PROVIDING INITIAL DIRECTION-OF-MOTION COMPATIBILITY.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION. 'COMPENDIUM OF HUMAN RESPONSES TO THE AEROSPACE ENVIRONMENT', NASA CR-1205(II), VOL II, SECTIONS 7-9, EDITED BY ROTH, E.M., LOVELACE FOUNDATION FOR MEDICAL EDUCATION AND RESEARCH, ALBUQUERQUE, N.M. FOR NASA, WASHINGTON, D.C. NOV. 1968

* ABSTRACT *

ABSTRACT (SECTION 7)
THE SPECTRUM OF ACCELERATION ENVIRONMENTS IS EXTREMELY LARGE AND MAY VARY IN DURATION, MAGNITUDE, RATE OF ONSET AND DECLINE, AND DIRECTION. SOME ACCELERATION EXPOSURES MAY BE SO MILD THAT THEY HAVE RELATIVELY NO PHYSIOLOGICAL OR PSYCHOPHYSIOLOGICAL EFFECTS, OR THEY MAY BECOME SO SEVERE THAT THEY PRODUCE MAJOR DISURBANCES. AFTER A REVIEW OF ACCELERATION IN THE THREE ORTHOGONAL AXES, THE ROTATING ENVIRONMENT, ANGULAR ACCELERATION, SUPERGRAVITY, ZERO GRAVITY, AND IMPACT ARE PRESENTED. VIBRATION IS COVERED SEPARATELY IN SECTION 8. (SECTION 9 CONCERNS SOUND AND NOISE.)

RUEHMAN, F.
DESIGN OF A MOTION SIMULATOR WITH SEVERAL DEGREES OF FREEDOM FOR ERGONOMICS STUDIES. (IN GERMAN). MUNICH TECHNICAL UNIV. MUNICH, WEST GERMANY. DEUTSCHE GESELLSCHAFT FUER ORTUNG UND NAVIGATION, NATIONAL TAGUNG UBER SIMULATION IN DIENSTE DES VERKEHRS, BREMEN, WEST GERMANY, APRIL 15-17, 1975.

* ABSTRACT *

A MOTION SIMULATOR HAS BEEN DEVELOPED TO PRODUCE COMBINED PITCH, ROLL, SWAY, AND HEAVE IN ORDER TO DETERMINE THE PSYCHOLOGICAL AND PHYSIOLOGICAL EFFECTS OF SUCH MOTION, ESPECIALLY ON TRACKING PERFORMANCE. THE MECHANICAL, HYDRAULIC AND ELECTRICAL COMPONENTS OF THE NEW DESIGN ARE DESCRIBED, ALONG WITH ITS CONTROL AND SURVEILLANCE SYSTEMS. UNLIKE THE MAJORITY OF PREVIOUS SIMULATORS, THE PRESENT DEVICE CAN INVESTIGATE THE INFLUENCE OF ROTATIONAL MOTION AND COMBINED LINEAR ACCELERATIONS.

RUGGLES, W.G. - ORIENTATOR
PATENT NO. 1,342,871
FILED APRIL 16, 1917 GRANTED JUNE 8, 1920

NR ABSTRACT

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RUGGLES, W.G. - ORIENTATOR
PATENT NO. 1,393,456
FILED SEP. 9, 1918 GRANTED OCT. 11, 1921

NA ABSTRACT

RUGGLES, J., KLIER, S., GAGE, H. AND VITALE, P. DESIGN FACTORS
IN ENVIRONMENTAL SIMULATION. 'NAVAL TRAINING DEVICE CENTER
REPORT: NAVTRADEVCEEN 66-C-0019-1, AD-880 048, DEC 1970.

* ABSTRACT *

A STUDY WAS CONDUCTED TO INVESTIGATE THE RELATIONSHIPS BETWEEN
VARIOUS ASPECTS OF COCKPIT MOTION AND PILOT PERFORMANCE. THE
TASK OF LANDING APPROACH WAS CARRIED OUT BY EXPERIENCED PILOTS
BOTH IN THE SIMULATOR AND IN THE AIRCRAFT. THE RESULTS OF THE
EXPERIMENT INDICATED THAT: BOTH EXPERIMENTAL APPARATUS AND
DESIGN VARIABLES OPERATED TO LIMIT THE CONCLUSIONS TO BE DRAWN
FROM THE STUDY; COMPARISONS BETWEEN PILOT PERFORMANCE IN THE
SIMULATOR AND THE ACTUAL AIRCRAFT WERE POSSIBLE BUT NOT MEANING-
FULLY RELATED TO THE EXPERIMENTAL QUESTIONS; AND WITH RESPECT TO
THE TEST OF THE RELATIONSHIPS BETWEEN PILOT PERFORMANCE AND
VARIATIONS IN THE MOTION CHARACTERISTICS, MEANINGFUL CONCLUSIONS
WERE NOT POSSIBLE BECAUSE OF EXPERIMENTAL APPARATUS AND DESIGN
DIFFICULTIES. THE STUDY PROVIDED VALUABLE KNOWLEDGE FOR
DEFINITION AND QUANTIFICATION OF SIMULATOR MOTION WHICH SHOULD
PROVE USEFUL IN FUTURE INVESTIGATIONS OF THE EFFECT OF SIMULATOR
MOTION UPON PERFORMANCE AND TRANSFER OF TRAINING. (AUTHOR)

RUGGLES, J.M., VITALE, P.A., AND PENFARI, R.C. KINETIC CUEING
IN SIMULATED CARRIER APPROACHES. U.S. NAVAL TRAINING DEVICE
CENTER, NAVTRADEVCEEN 1432-1, 1965.

* ABSTRACT *

TWELVE PILOTS, TEN TRAINED IN STATIC AND TWO IN DYNAMIC COCKPITS
AFTER BEING INITIALLY MATCHED IN DYNAMIC COCKPIT TASKS,
PERFORMED CARRIER LANDING EXERCISES IN DYNAMIC COCKPIT (PITCH
AND ROLL ACCELERATIONS). GROUP TRAINED WITHOUT MOTION CUES
USED MORE VARIABLE AND LESS APPROPRIATE CONTROL INPUTS AND, IN
GENERAL, PERFORMED LESS WELL. EXPERIENCED PILOT'S PERFORMANCE
DETERIORATES IMMEDIATELY WHEN COCKPIT MOTION CUES ARE WITHDRAWN,
AND DOES NOT IMPROVE WITH PRACTICE IN STATIC SIMULATION.

RUST, S.K., CAPT USAF
FLIGHT SIMULATOR FIDELITY ASSURANCE. PROCEEDINGS OF THE 8TH
ATTC/INDUSTRY CONFERENCE, 18-20 NOV 1975.

* ABSTRACT *

THIS PAPER DISCUSSED THE PROBLEMS ENCOUNTERED DURING TEST AND ACCEPTANCE OF THE ADVANCED SIMULATOR FOR UNDERGRADUATE PILOT TRAINING (ASUPT) AS SEEN BY THE AUTHOR, A T-37 INSTRUCTOR PILOT.

THE IMPORTANCE OF LAG TIME AND CORRELATION OF THE VISUAL AND MOTION CUES WAS EMPHASIZED. AT THE TIME OF THIS REPORT, TRANSPORT DELAY FROM PILOT INPUT TO SYSTEM OUTPUT FOR MOTION WAS 100-233 MS, AND FOR THE VISUAL IT WAS 100 MS. MOTION SYSTEM LAG THEN INCREASED AS A FUNCTION OF PILOT INPUT FREQUENCY, WHILE THE VISUAL LAG REMAINED CONSTANT. ACCORDING TO CAPT RUSTIS OBSERVATIONS, THE RESULTS OF THESE TIME DISCREPANCIES WERE OVERCONTROL OF PILOT INDUCED OSCILLATIONS (PIO), PARTICULARLY IN ROLL. THE EFFECTS WERE ALSO APPARENT IN FORMATION FLYING. FORMATION FLIGHT, THE MOST PRECISE FLYING DONE IN THE T-37'S WAS A LITTLE ROUGH. PILOTS COULD NOT HOLD POSITION AS WELL AS THEY COULD IN ACTUAL FLIGHT. IN THE AUTHOR'S OPINION, "...WE ARE ONLY 100-200 MILLISECONDS AWAY FROM SOLVING THAT PROBLEM." CUT THE LAG TIME, AND FORMATION FLYING WILL ALSO SMOOTH OUT.

AN INTERESTING OBSERVATION WAS MADE WHEN A PILOT (WHO HADN'T FLOWN ASUPT BEFORE) WAS FLYING AEROBATICS SUCH AS A LOOP USING MOTION. TYPICALLY, IN THE PULLOUT, HE OVERCONTROLLED ROLL TRYING TO KEEP WINGS LEVEL. HOWEVER, WHEN MOTION WAS TURNED OFF AND HE DIDN'T GET THE DELAYED MOTION CUE, THE OVERCONTROLLING WAS DECREASED BY ABOUT 50%.

SADOFF, M. THE EFFECTS OF LONGITUDINAL CONTROL-SYSTEM DYNAMICS ON PILOT OPINION AND RESPONSE CHARACTERISTICS AS DETERMINED FROM FLIGHT TESTS AND FROM GROUND SIMULATOR STUDIES
AMES RESEARCH CENTER, NATIONAL AERONAUTICS AND SPACE ADMINIS-
TRATION MEMORANDUM 10-1-58A, OCT. 1958.

* ABSTRACT *

THE RESULTS OF A FIXED-BASE SIMULATOR STUDY OF THE EFFECTS OF VARIABLE LONGITUDINAL CONTROL-SYSTEM DYNAMICS ON PILOT OPINION ARE PRESENTED AND COMPARED WITH FLIGHT TEST DATA. THE CONTROL-SYSTEM VARIABLES CONSIDERED IN THIS INVESTIGATION INCLUDED STICK FORCE PER G, TIME CONSTANT, AND DEADBAND, OR STABILIZER BREAKOUT FORCE. IN GENERAL, THE FAIRLY GOOD CORRELATION BETWEEN FLIGHT AND SIMULATOR RESULTS FOR TWO PILOTS DEMONSTRATES THE VALIDITY OF FIXED-BASE SIMULATOR STUDIES WHICH ARE DESIGNED TO COMPLEMENT AND SUPPLEMENT FLIGHT STUDIES AND SERVE AS A GUIDE IN CONTROL-SYSTEM PRELIMINARY DESIGN. HOWEVER, IN THE INVESTIGATION OF CERTAIN PROBLEM AREAS (E.G., SENSITIVE CONTROL-SYSTEM CONFIGURATIONS ASSOCIATED WITH PILOT-INDUCED OSCILLATIONS IN FLIGHT), FIXED-BASE SIMULATOR RESULTS DID NOT PREDICT THE OCCURRENCE OF AN INSTABILITY, ALTHOUGH THE PILOTS NOTED THE SYSTEM WAS EXTREMELY SENSITIVE AND UNSATISFACTORY. IF IT IS DESIRED TO PREDICT PILOT-INDUCED OSCILLATION TENDENCIES, TESTS IN MOVING-BASE SIMULATORS MAY BE REQUIRED.

IT WAS FOUND POSSIBLE TO REPRESENT THE HUMAN PILOT BY A LINEAR PILOT ANALOG FOR THE TRACKING TASK ASSUMED IN THE PRESENT STUDY. THE CRITERION USED TO ADJUST THE PILOT ANALOG WAS THE ROOT-MEAN-SQUARE TRACKING ERROR OF ONE OF THE HUMAN PILOTS ON THE FIXED-BASE SIMULATOR. MATCHING THE TRACKING ERROR OF THE PILOT ANALOG TO THAT OF THE HUMAN PILOT GAVE AN APPROXIMATION TO THE VARIATION OF HUMAN-PILOT BEHAVIOR OVER A RANGE OF CONTROL-SYSTEM DYNAMICS.

RESULTS OF THE PILOT-ANALOG STUDY INDICATED THAT BOTH FOR OPTIMIZED CONTROL-SYSTEM DYNAMICS (FOR POOR AIRPLANE DYNAMICS) AND FOR A REGION OF GOOD AIRPLANE DYNAMICS, THE PILOT RESPONSE CHARACTERISTICS ARE APPROXIMATELY THE SAME.

FOR ONE PROBLEM AREA, WHERE PILOT-INDUCED OSCILLATIONS WERE EXPERIENCED IN FLIGHT, PILOT-ANALOG TRACKING-RESPONSE CHARACTERISTICS INDICATED A VERY CRITICAL ADJUSTMENT OF GAIN (OR FORCE COMMANDED PER UNIT ERROR) WAS REQUIRED TO AVOID EITHER POOR RESPONSE OR INSTABILITY. WHILE THIS ADJUSTMENT COULD BE MADE BY THE HUMAN PILOTS ON THE FIXED-BASE SIMULATOR, IT COULD NOT BE COPIED WITH IN FLIGHT APPARENTLY BECAUSE OF ADVERSE MOTION-FEEDBACK EFFECTS. THESE RESULTS SUGGEST THAT PILOT ANALOG TRACKING-RESPONSE CHARACTERISTICS, WHICH EXHIBIT A CRITICAL DEPENDENCE ON VARIATIONS IN PILOT-ANALOG GAIN, MAY PROVIDE A USEFUL CRITERION FOR PREDICTING TENDENCIES TOWARD PILOT-INDUCED OSCILLATIONS IN FLIGHT.

SADOFF, M. A STUDY OF A PILOT'S ABILITY TO CONTROL DURING SIMULATED STABILITY AUGMENTATION SYSTEM FAILURES. NASA TECHNICAL NOTE D-1552, AMES RESEARCH CENTER, MOFFETT FIELD, CA, NOV. 1962.

* ABSTRACT *

THE RESULTS PRESENTED SHOW THE EFFECTS OF FAILURE OF A STABILITY AUGMENTATION SYSTEM ON THE PILOT'S ABILITY TO CONTROL WHILE ENGAGED IN A SIMPLE TRACKING TASK. THE RESULTS OF FAILURES SIMULATED IN A FIXED AND MOVING-CAB CENTRIFUGE SUGGEST THAT MOVING COCKPIT FLIGHT SIMULATORS PROVIDE A MORE REALISTIC EVALUATION OF THE TRANSIENT EFFECTS OF STABILITY AUGMENTER FAILURES. IN THE PRESENT STUDY, SIMULATOR MOTIONS GENERALLY INTERFERED WITH THE ABILITY OF THE PILOTS TO ADAPT TO THE FAILURES. A PENCIL-TYPE SIDE-ARM CONTROLLER PROVED EASIER TO USE THAN A CONVENTIONAL CENTER STICK IN COPING WITH PITCH DAMPER FAILURES AT THE HIGHER SHORT-PERIOD FREQUENCIES. THE USE OF SIMPLE PILOT MODELS IN THE ANALYSIS AND PREDICTION OF THE TRANSIENT EFFECTS OF STABILITY AUGMENTER FAILURES PROVIDED ENCOURAGING RESULTS.

COMPARISON OF PILOT PERFORMANCE IN STATIC AND DYNAMIC CENTRIFUGE SIMULATION OF LONGITUDINAL STABILITY AUGMENTER FAILURES WHILE PILOTS PERFORMING PITCH TRACKING TASK. DYNAMIC RUNS CONDUCTED AT

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A 3 G BIAS TO ELIMINATE DISORIENTATION PRODUCED AT 1 G (BY SPURIOUS SURGE AND SWAY ACCELERATIONS PARTICULARLY). TWO PILOTS PRODUCED MOST OF THE DATA. ARGUED (BUT NOT CONCLUSIVELY DEMONSTRATED FROM THE INCOMPLETELY PRESENTED DATA) THAT MOTION IS IMPORTANT SINCE IT INCREASES BOTH THE TIME TO ADAPT AND THE MEAN-SQUARED ERROR DURING ADAPTATION.

SADOFF, M. AND HARPER, C.W. PILOTED FLIGHT SIMULATOR RESEARCH: A CRITICAL REVIEW. AEROSPACE ENG. 21, 50-63, 1962.

* ABSTRACT *

CITES OTHERWISE UNPUBLISHED NASA AMES WORK.

THREE PILOTS TRYING TO CONTROL SUPERSONIC TRANSPORT WITH ALL DAMPERS IMPERATIVE AND AFTER ENGINE FAILURE. IN STATIC SIMULATION, PILOTS DID NOT KNOW WHICH INSTRUMENT MOTIONS TO CONTROL FIRST, AND PERFORMED BADLY. IN AMES 5 DF SIMULATION, ROLL (AND SWAY) MOTIONS INDICATED WHAT TO CONTROL FIRST, AND PILOTS PERFORMED WELL.

VECTAL HOVER, WITH 6 DF INSTRUMENTS, IMPOSSIBLE IN STATIC SIMULATOR BUT FAIRLY EASY IN SIMULATOR HAVING PITCH AND ROLL DYNAMICS.

STBL YAW AND SWAY PROBLEM DURING 60-70 KNOTS APPROACH AND LANDING. DISAGREEMENT IN PILOT OPINION BETWEEN STATIC SIMULATOR STUDIES AND FLIGHT INVESTIGATION CONSIDERED DUE TO RESTRICTED VISION IN SIMULATOR, NOT TO ABSENCE OF MOTION.

SADOFF, M., MCFADDEN, N.M. AND HEINLE, D.R. A STUDY OF LONGITUDINAL CONTROL PROBLEMS AT LOW AND NEGATIVE DAMPING AND STABILITY WITH EMPHASIS ON EFFECTS OF MOTION CUES, NASA TN D-348, 1961.

* ABSTRACT *

INCOMPLETE OR SPURIOUS MOTION CUES AS MIGHT ARISE IN SOME FORMS OF SIMULATION INCLUDING CENTRIFUGES, ARE IMPORTANT ONLY FOR HIGH FREQUENCY LIGHTLY DAMPED DYNAMICS.

COMPARISON OF 6 PILOTS' OPINIONS OF LONGITUDINAL DYNAMICS FROM STUDIES IN STATIC SIMULATOR, DYNAMIC (PITCH AND ROLL) SIMULATOR, CENTRIFUGE (ROTATABLE GONDOLA) SIMULATOR, AND VARIABLE STABILITY AIRCRAFT. CENTRIFUGE RUNS CONDUCTED AT A 3 G BIAS TO ELIMINATE DISORIENTATION PRODUCED AT 1 G (BY SPURIOUS SURGE AND SWAY ACCELERATIONS PARTICULARLY). DATA FROM ALL FOUR SITUATIONS IN FAIRLY GOOD GENERAL AGREEMENT. INCOMPLETE OR SPURIOUS MOTION CUES (STATIC AND CENTRIFUGE SIMULATIONS) IMPORTANT ONLY FOR HIGH FREQUENCY, LIGHTLY DAMPED DYNAMICS. DATA FROM PITCH AND ROLL

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SIMULATOR (ACCURATE ANGULAR ACCELERATION CUES) COMPARED MOST FAVORABLY WITH FLIGHT; CENTRIFUGE (ACCURATE NORMAL LINEAR, BUT INACCURATE LONGITUDINAL LINEAR AND PITCH ANGULAR ACCELERATION CUES) GAVE RISE TO POORER PILOT OPINION THAN FLIGHT.

ST. JOHN, E. - APPARATUS FOR USE IN TEACHING AND TRAINING AVIATORS
PATENT NO. 2,369,418
FILED APRIL 24, 1943 GRANTED FEB. 13, 1945

NO ABSTRACT

SCHALMBERG, G.F. AND HEAPY, R.J. EVALUATION OF AN AIRSEAR AS A LIMITED COCKPIT MOTION SYSTEM. MCDONNELL-DOUGLAS CORPORATION, DOUGLAS AIRCRAFT COMPANY, 3855 LAKEWOOD BLVD, LONG BEACH, CALIFORNIA 90801, U.S.A. MDC J-0071, 1969.

* ABSTRACT *

EQUIPMENT
THE DYNASEAT AS USED IN THIS EXPERIMENT IS DESIGNED TO PRODUCE A SENSATION OF MOTION BY COMPUTER-CONTROLLED AIR INFLATION OF A COMPARTMENTAL SEAT AND BACK CUSHION. THE SEAT WAS FITTED IN A DC-9 FIXED BASE 'ALL WEATHER LANDING' SIMULATOR.

SUBJECTS
FOUR DC-9 TEST PILOTS TOOK PART.

METHOD
THE AUTHORS INVESTIGATED THE EFFECT OF THE DYNASEAT ON SIMULATOR FIDELITY AND PILOT PERFORMANCE DURING APPROACH AND LANDING SEQUENCES UNDER VARIOUS ENVIRONMENTAL CONDITIONS. THESE ENVELOPED TWO SEAT CONDITIONS - SEAT OPERATIVE AND SEAT INOPERATIVE, TWO WIND CONDITIONS - NO WIND AND A FOURTEEN KNOT CROSS WIND, AND THREE TURBULENCE CONDITIONS - NO TURBULENCE, LIGHT TURBULENCE AND MODERATE TURBULENCE. AFTER THREE PRELIMINARY TRIALS, EACH PILOT FLEW 36 APPROACH AND LAND RUNS PRESENTED IN A RANDOM BLOCK DESIGN. THE DEPENDENT VARIABLES, RECORDED FROM THE BEGINNING OF EACH RUN UNTIL TOUCHDOWN WERE:

(A) THE INTEGRAL OF THE ABSOLUTE 'ERROR' OF ROLL COMMAND, AND
(B) THE INTEGRAL OF THE ABSOLUTE 'ERROR' OF PITCH COMMAND.

THE DEPENDENT VARIABLES REGARDED AT TOUCHDOWN WERE:

1. SINK RATE IN FEET/SECOND
2. PITCH ANGLE IN DEGREES.
3. ROLL ANGLE IN DEGREES.
4. PITCH RATE IN DEGREES/SECOND.
5. ROLL RATE IN DEGREES/SECOND.
6. LONGITUDINAL TD POINT, AND
7. LATERAL TD POINT.

IN ADDITION EACH SUBJECT COMPLETED A QUESTIONNAIRE. PERFORMANCE

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MEASURES WERE EXAMINED USING A SUBJECTS X SEAT X WIND X TURBU-
LENCE REPLICATED ANALYSES OF VARIANCE TEST.

CONCLUSION

THE SUBJECTIVE AND OBJECTIVE RESULTS INDICATED THAT THE DYNASEAT
DID NOT ENHANCE APPROACH AND TOUCHDOWN PILOT PERFORMANCE NOR DID
IT ADD REALISM TO THE SIMULATION.

SCHELFORN, A.E., A STUDY OF THE DYNAMIC RESPONSE CHARACTERISTICS
OF FLIGHT SIMULATORS. WRIGHT-PATTERSON AFB, OHIO: WRIGHT AIR
DEVELOPMENT CENTER, AIR RESEARCH AND DEVELOPMENT COMMAND, TECH-
NICAL REPORT 59-98, APRIL 1959.

* ABSTRACT *

THE ABILITY OF A FLIGHT SIMULATOR TO SOLVE THE CHARACTERISTIC
FLIGHT EQUATIONS OF AN AIRCRAFT IS DEPENDENT UPON THE DYNAMIC
AND SMALL MOTION PERFORMANCE OF THE MECHANICAL, ELECTRONIC AND
SERVO ELEMENTS OF THE SIMULATOR COMPUTER. ONE AC ANALOG
SIMULATOR AND ONE DC ANALOG SIMULATOR WERE TESTED FOR SMALL
AMPLITUDE LONGITUDINAL DYNAMIC RESPONSE UTILIZING PULSE, RAMP,
STEP, SINUSOIDAL AND SQUARE WAVE INPUTS. THE PURPOSE OF THE
TESTS WAS TO DETERMINE AND ANALYZE THE OVER-ALL DYNAMIC
PERFORMANCE AND THE COMPONENT PERFORMANCE OF THE AC AND DC
ANALOG SIMULATORS AND FROM THE RESULTS OF THE TESTING, PREPARE A
SPECIFICATION ESTABLISHING REQUIREMENTS, TESTS AND TOLERANCES
FOR DYNAMIC RESPONSE OF FUTURE FLIGHT SIMULATORS.

THIS REPORT CONTAINS AN ANALYSIS OF THE DYNAMIC PERFORMANCE OF
THE COMPUTERS AND VARIOUS COMPONENTS UTILIZED IN THE SIMULATORS
TESTED. REPRESENTATIVE COPIES OF OSCILLOGRAPH RECORDS TAKEN AT
THE SIMULATORS, SHOWING COMPUTER RESPONSE TO THE VARIOUS INPUTS
ARE INCLUDED. REQUIREMENTS, TESTS AND TOLERANCES UTILIZED IN
PREPARATION OF THE SPECIFICATION ARE PRESENTED AND DISCUSSED IN
THE REPORT.

SCHMID, R.M. SYSTEMS ANALYSIS OF THE VESTIBULO-OCULAR SYSTEM.
FIFTH SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE
EXPLORATION, HELD AT THE NAVAL AEROSPACE MEDICAL RESEARCH LAB.,
PENSACOLA, FL., AUG. 19-21, 1970. PUBLISHED AS NASA SP-314,
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., D.C.,
1973.

* ABSTRACT *

THE VESTIBULO-OCULAR SYSTEM IS EXAMINED FROM THE STANDPOINT OF
SYSTEM THEORY. THE EVOLUTION OF A MATHEMATICAL MODEL OF THE
VESTIBULO-OCULAR SYSTEM IN AN ATTEMPT TO MATCH MORE AND MORE
EXPERIMENTAL DATA IS FOLLOWED STEP BY STEP. THE FINAL MODEL
EXPLAINS MANY CHARACTERISTICS OF THE EYE MOVEMENT IN VESTIBU-

LARLY INDUCED NYSTAGMUS. THE ANALYSIS OF THE DYNAMIC BEHAVIOR OF THE MODEL AT THE DIFFERENT STAGES OF ITS DEVELOPMENT IS ILLUSTRATED IN TIME DOMAIN, MAINLY IN A QUALITATIVE WAY.

SCHMIDT, S.F. AND CONRAD, B.
MOTION DRIVE SIGNALS FOR PILOTED FLIGHT SIMULATORS.
ANALYTICAL MECHANICS ASSOCIATES INC. PALO ALTO, CA. FOR AMES
RESEARCH CENTER, NASA CONTRACTOR REPORT. NASA CR-1601, MAY 1970

* ABSTRACT *

AN IMPORTANT ASPECT OF MANY PILOTED FLIGHT SIMULATORS IS THEIR ABILITY TO PROVIDE REALISTIC MOTION CUES. SINCE SUCH SIMULATORS ARE CONSTRAINED TO MOVE WITHIN THE CONFINES OF THEIR MECHANICAL DRIVE SYSTEMS, THEY CANNOT DUPLICATE ALL THE MOTIONS (AND HENCE ALL THE MOTION CUES) ASSOCIATED WITH A REAL AIRCRAFT. IN ORDER TO USE THE LIMITED MOTION CAPABILITIES OF A SIMULATOR EFFECTIVELY IT IS THUS NECESSARY TO

- (A) DETERMINE WHICH MOTION CUES ARE IMPORTANT TO A PILOT;
- (B) SYNTHESIZE LOGIC FOR COMMANDING MOTION ACHIEVABLE BY THE DRIVE SYSTEM AND REALISTIC TO A PILOT.

THIS REPORT SUMMARIZES A MATHEMATICAL APPROACH TO THIS PROBLEM AND PRESENTS LOGIC SYNTHESIZED FOR THE AMES ALL-AXIS MOTION GENERATOR. BOTH THE THEORY DEVELOPED AND THE LOGIC PRESENTED SHOULD BE APPLICABLE TO A WIDE VARIETY OF MOTION SIMULATION PROBLEMS.

SCHMIDT, S.F. AND CONRAD, B. A STUDY OF TECHNIQUES FOR CALCULATING MOTION DRIVE SIGNALS FOR FLIGHT SIMULATORS. REPORT NO. 71-28, ANALYTICAL MECHANICS ASSOCIATES INC., JULY 1971. (AVAILABLE AS NASA CR-114345)

* ABSTRACT *

THE OBJECTIVES OF THE STUDY EFFORT DESCRIBED IN THIS REPORT WERE AS FOLLOWS:

1. DEVELOP AN EXPERIMENTAL TEST PLAN USING THE FORMATION-FLYING TASK FOR THE VALIDATION AND REFINEMENT OF THE WASHOUT CIRCUITS DESCRIBED IN REFERENCE 1. THE DETAILS OF THIS PLAN ARE GIVEN IN SECTION 2.
2. EXECUTE THE TEST PLAN IN CONJUNCTION WITH NASA SCIENTISTS AND TEST PILOTS ON THE AMES SIMULATION FACILITIES. SOME OF THE EXPERIMENTAL RESULTS OBTAINED IN THESE TESTS ARE GIVEN IN SECTION 3.
3. ANALYZE THE EXPERIMENTAL DATA IN CONJUNCTION WITH NASA

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SCIENTISTS, USING PILOT MODEL IDENTIFICATION METHODS. DIFFICULTIES ENCOUNTERED WITH THESE PROCEDURES ARE GIVEN IN SECTION 4, ALONG WITH A FEW PRELIMINARY RESULTS.

4. DEVELOP FORTRAN IV WASHOUT PROGRAMS FOR APPLICATIONS ON THE AMES 11-AXIS SIMULATOR. TWO SUCH PROGRAMS ARE DESCRIBED IN THE APPENDIX. SECTION 5 DESCRIBES THE USE OF THESE CIRCUITS.

5. DEVELOP A QUESTIONNAIRE-TYPE LOG TO ASSIST NASA PERSONNEL IN DOCUMENTING THE EXPERIENCE OBTAINED WITH THE APPLICATION OF WASHOUT CIRCUITS TO OPERATIONAL SIMULATIONS. THIS LOG IS PRESENTED IN SECTION 6.

SCHWEINFURTH, R. AND SCHMIDTLEIN, H. REPORT OF THE DGLR SYMPOSIUM, FLIGHT MECHANICAL SIMULATION - ON THE GROUND OR IN THE AIR, HELD AT DUSSELDORF ON DEC. 4, 1970. GERMAN AIR AND SPACE-FLIGHT REPORT 70-29, MAY 1971. TRANSLATED BY THE FOREIGN TECHNOLOGY DIVISION, WRIGHT-PATTERSON AFB, OHIO, AS REPORT FTD-HC-23-1553-72, 9 JUL 1973.

* ABSTRACT *

THIS REPORT IS A COMPILATION OF NINE GERMAN PAPERS CONCERNING FLIGHT SIMULATION. THE TOPICS INCLUDE VISUAL SIMULATION, FIXED AND MOVING-BASE SIMULATION, IN-FLIGHT SIMULATION, AND THE EVALUATION AND EFFECTIVENESS OF SIMULATION.

CONTENTS:

USE OF FLIGHT SIMULATORS WITHOUT VISUAL AND MOTION IMPRESSIONS OF THE PILOT (R. SCHWEINFURTH);

THE INFLUENCE OF MOTION IMPRESSIONS ON PILOTING ERRORS IN SIMULATED ILS APPROACHES (R. ERDMANN AND R. DIERKE);

THE EFFECTIVENESS OF A FLIGHT SIMULATOR FOR SPECIAL MISSIONS (H.M. FRANKE AND P. SEPP);

FLIGHT MECHANICAL TAKEOFF AND LANDING INVESTIGATIONS OF A VTOL AIRCRAFT USING VARIOUS CONTROL SYSTEMS DURING HOVERING FLIGHT (H. KOLAR AND G. SCHNEIDER);

FLIGHT MECHANICAL SIMULATION FROM THE USER'S POINT OF VIEW (H. FRIEDRICH);

EVALUATION OF FREE FLIGHT SIMULATIONS WITH A HELICOPTER HAVING A VARIABLE STABILITY AND CONTROLLABILITY WITH APPLICATIONS TO AIRCRAFT DESIGN (H. SCHMIDTLEIN);

CONTRIBUTIONS TO THE SIMULATION RANGE AND PARAMETER SENSITIVITY OF AIRBORNE SIMULATORS (B. UHRMEISTER);

THE AIRBORNE SIMULATOR HFB 320 HANSA PRESENT CONDITIONS AND
PLANS (A. PIETRASS);

V/STOL TECHNOLOGY AS AN APPLICATION FOR AIRBORNE SIMULATION
(K. JANIK).

SCHWEIZER, G. PILOT BEHAVIOR IN VTOL AIRCRAFT. NORTH ATLANTIC
TREATY ORGANIZATION ADVISORY GROUP FOR AEROSPACE RESEARCH
AND DEVELOPMENT REPORT 521', OCT. 1965.

* ABSTRACT *

INFORMATION ABOUT THE HANDLING QUALITIES OF NEW AEROPLANES WHICH
ARE IN THE DEVELOPMENT STAGE IS VERY IMPORTANT, SINCE THE
CONTROL SYSTEM, THE AUTOSTABILISER AND PART OF THE AVIONICS
SYSTEM ARE STRONGLY INFLUENCED BY THE HANDLING QUALITIES OF THE
AIRCRAFT. SINCE THE PILOT IS NEARLY ALWAYS INCLUDED IN THE
CONTROL LOOP FOR GUIDANCE AND STABILITY, IT IS DIFFICULT TO
OBTAIN OBJECTIVE, QUANTITATIVE INFORMATION ABOUT THE HANDLING
QUALITIES. IN THE COURSE OF THE D8 31 DEVELOPMENT PROGRAMME,
MANY FLIGHT TESTS WERE CARRIED OUT WITH A HOVERING RIG TO
INVESTIGATE THE HANDLING QUALITIES OF THE AEROPLANE. THE MAIN
AIM OF THE FLIGHT TESTS WAS TO OBTAIN OBJECTIVE INFORMATION IN
ADDITION TO THE SUBJECTIVE OPINION OF THE PILOT. THE AMPLITUDE
DISTRIBUTION FUNCTIONS FOR CONTROL MOMENTS AND THE POWER SPECTRA
OF THE CONTROL DEFLECTIONS HAVE PROVED TO BE IMPORTANT AIDS.
TEST RUNS, IN WHICH THE EXPECTED FLIGHT CONDITIONS WERE
SIMULATED ON A SMALL HOVERING RIG, WERE OF GREAT USE. (AUTHOR)

SEAY, D. L.
SIMULATOR PERFORMANCE VALIDATION AND IMPROVEMENT THROUGH
RECORDED DATA.
AIAA PAPER NO. 73-938

* ABSTRACT *

DURING THE DEVELOPMENT OF TWO-SEGMENT APPROACH PROCEDURES
INSTRUMENTATION SYSTEMS WERE INSTALLED ON A 727 FLIGHT SIMULATOR
TO MONITOR A VARIETY OF FLIGHT PARAMETERS. PARAMETERS MONITORED
AND DATA FORMAT WERE DESIGNED TO BE THE SAME AS THOSE TO BE
USED IN LATER FLIGHT TESTS WITH LINE AIRCRAFT. GOOD CORRELATION
EXISTED BETWEEN SIMULATOR AND AIRCRAFT DATA IN MANY AREAS.
PREVIOUSLY IDENTIFIED AREAS OF POOR SIMULATION WERE CHECKED WITH
QUANTITATIVE DATA. THE OBJECTIVE DATA OBTAINED COULD BE USED
FOR SIMULATION IMPROVEMENTS IN AREAS PREVIOUSLY CHANGED
PRIMARILY BY USING SUBJECTIVE DATA OBTAINED FROM PILOTS. AREAS
WHERE SIMILAR TECHNIQUES COULD IMPROVE SIMULATION WERE
IDENTIFIED.

SECKEL, E., HALL, I.A.M., MCRUER, D.T. AND WEIR, D.H. 'HUMAN PILOT DYNAMIC RESPONSE IN FLIGHT AND SIMULATOR'. WRIGHT AIR DEVELOPMENT CENTER TR-57-520, 1958.

* ABSTRACT *

RESULTS OF AN EFFORT TO DETERMINE DIFFERENCES IN PILOT TRACKING BEHAVIOR IN FLIGHT AND IN A FLIGHT SIMULATOR ARE PRESENTED. THE EXPERIMENT WAS DESIGNED TO ESTIMATE THE QUASI-LINEAR DESCRIBING FUNCTIONS AND LINEAR CORRELATIONS OF SEVERAL PILOTS WHEN ENGAGED IN LATERAL AND LONGITUDINAL TRACKING TASKS.

STATISTICAL ANALYSES OF DESCRIBING FUNCTION AND LINEAR CORRELATION DATA REVEALED: (1) INDIVIDUAL PHASE ANGLE, AMPLITUDE RATIO, AND LINEAR CORRELATION DATA WERE APPROXIMATELY NORMALLY DISTRIBUTED ABOUT THEIR MEANS; (2) SIGNIFICANT DIFFERENCES IN THE MEAN VALUES OF PILOT'S DESCRIBING FUNCTIONS WERE NOTED FOR PHASE ANGLE AND AMPLITUDE RATIO IN LONGITUDINAL FLIGHT, AND FOR PHASE ANGLE IN LATERAL FLIGHT; (3) SIGNIFICANT DIFFERENCES IN LINEAR CORRELATIONS BETWEEN FLIGHT AND SIMULATOR WERE NOTED; (4) SIGNIFICANT DIFFERENCES WERE NOTED IN THE VARIANCES FOR LATERAL AMPLITUDE RATIO AND LATERAL AND LONGITUDINAL PHASE, BUT NOT FOR LONGITUDINAL AMPLITUDE RATIO OR LATERAL AND LONGITUDINAL LINEAR CORRELATIONS; (5) THE RESULTS IMPLIED THAT THE PILOT'S EFFECTIVE REACTION TIME DELAY WAS LONGER IN FLIGHT AND THAT HIS GAIN WAS LOWER.

J.L. SERAFIN - SIMULATED AIRCRAFT
PATENT NO. 2,695,783
FILED JULY 27, 1953 GRANTED NOV. 30, 1954

NO ABSTRACT

SGRP, J.A. AND DOUGHERTY, D.J. CONTACT ANALOG SIMULATOR EVALUATIONS: HOVERING AND AIR TAXI MANEUVERS. JANAIR JOINT ARMY-NAVY AIRCRAFT INSTRUMENTATION RESEARCH REPORT, D228-421,016. BELL HELICOPTER CO. FOR OFFICE OF NAVAL RESEARCH, JULY 1963.

* ABSTRACT *

FOUR SUBJECTS WERE REQUIRED TO PERFORM THREE BASIC FLIGHT MANEUVERS IN THE BELL HELICOPTER COMPANY DYNAMIC SIMULATOR. THESE MANEUVERS WERE PRESENTED AT VARIOUS ASSIGNED FLIGHT CONDITIONS FOR FOUR BASIC CONFIGURATIONS OF THE JANAIR VERTICAL DISPLAY. THE THREE MANEUVERS WERE: (1) HOVERING, (2) TAKEOFF, HOVER AND TOUCHDOWN, AND (3) TAKEOFF, AIR TAXI AND TOUCHDOWN.

THE DYNAMIC PLATFORM USED WAS A HYDRAULICALLY ACTUATED, SERVO-CONTROLLED SYSTEM CAPABLE OF RESPONDING WITH SIX DEGREES OF

FREEDOM. THE PLATFORM LIMITS OF TRAVEL FOR THE THREE ANGULAR MOTIONS INCLUDED: 10 DEGREES OF PITCH, ROLL AND YAW. MAXIMUM ACCELERATION WAS 40 DEGREES PER SECOND SQUARED FOR YAW. THE TRANSLATIONAL MOTIONS ALONG THE LONGITUDINAL AND LATERAL AXES WERE USED PRIMARILY AS COMPENSATORY MOTIONS TO REPRODUCE PITCH AND YAW RESPONSES WITH GREATER FIDELITY. VERTICAL MOTION WAS THE ONLY TRANSLATIONAL MOTION WHICH WAS DYNAMICALLY SIMULATED. THE LIMITS OF TRAVEL WERE $\pm 0R = 3.5$ FEET, WITH A MAXIMUM ACCELERATION OF 6.5 FEET PER SECOND SQUARED. THE PLATFORM IS DESCRIBED IN DETAIL BY WILLIS (1960, 1962) AND FEDDERSEN (1962). MOTION EQUATIONS FOR HOVERING EXPERIMENT ARE PRESENTED BY HACKLER (1960).

SHIRACHI, D.K. AND SHIRLEY, R.S. THE EFFECT OF A VISUAL/MOTION DISPLAY MISMATCH IN A SINGLE AXIS COMPENSATORY TASK. NATIONAL AERONAUTICS & SPACE ADMINISTRATION, AMES RESEARCH CENTER, REPORT NASA CR-2921, OCT. 1977.

* ABSTRACT *

AN EXPERIMENT IS PERFORMED TO DETERMINE THE EFFECT OF A PERFORMANCE MISMATCH BETWEEN THE VISUAL AND MOTION DISPLAY SYSTEMS ON A REAL-TIME PILOTED AIRCRAFT SIMULATION (USUALLY MOTION DISPLAYS EXHIBIT MORE PHASE LAG THAN VISUAL DISPLAYS). PILOTS PERFORM A COMPENSATORY ROLL TRACKING TASK WITH DYNAMICS TYPICAL OF MEDIUM JET TRANSPORTS. BETWEEN 0 AND 10 RAD/SEC, VISUAL AND MOTION SYSTEM RESPONSES ARE EQUIVALENT TO EITHER UNITY OR A FIRST ORDER LAG AT 4.8 RAD/SEC. PILOT DESCRIBING FUNCTIONS AND ERROR SCORES ARE CALCULATED. RESULTS SHOW THAT THE MISMATCH BETWEEN VISUAL AND MOTION DISPLAY SYSTEMS HAS NO SIGNIFICANT EFFECT; RATHER, IT IS THE ABSENCE OF HIGH FREQUENCY VISUAL AND/OR MOTION CUES WHICH SIGNIFICANTLY AFFECTS PILOT PERFORMANCE.

SHIRLEY, R.S. AND JONES, A.D. SAFE: SIX AXIS FREQUENCY EVALUATION OF A MOTION SIMULATOR COMPUTER SCIENCES CORPORATION, MOUNTAIN VIEW, CALIFORNIA. AIAA VISUAL AND MOTION SIMULATION CONFERENCE, PALO ALTO, CALIF. SEPTEMBER 10 - 12, 1973, PAPER NO. 73-932 L 73-666-19

* ABSTRACT *

SAFE IS A DIGITAL COMPUTER PROGRAM USED TO CHECK THE RESPONSE OF AN AIRCRAFT MOTION SIMULATOR. SAFE DRIVES EACH AXIS OF THE SIMULATOR NEAR ITS ACCELERATION, VELOCITY AND POSITION LIMITS, RECORDING THE SIMULATOR MOTIONS FOR COMPARISON WITH NOMINAL RESPONSES. SAFE ALSO DRIVES UP TO SIX AXES AT ONCE TO MEASURE THE FREQUENCY RESPONSE AND NOISE LEVELS OF EACH AXIS. TOGETHER THESE TWO MEASUREMENTS PROVIDE A SENSITIVE CHECK OF THE ENTIRE MOTION SYSTEM, YET THEY CAN BE COMPLETED IN LESS THAN TEN MINUTES.

SHIRLEY, R.S. AND YOUNG, L.R. MOTION CUES IN MAN-VEHICLE CONTROL. IN FOURTH ANNUAL NASA-UNIVERSITY CONFERENCE ON MANUAL CONTROL, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN, MARCH 21-23, 1968. NASA DOCUMENT SP-192.

* ABSTRACT *
THE HUMAN OPERATOR'S USE OF ROLL-ANGULAR-MOTION CUES IN MAN-VEHICLE CONTROL IS INVESTIGATED. EXTENSIVE DATA FOR THE HUMAN OPERATOR'S DESCRIBING FUNCTION AND REMNANT ARE TAKEN FOR A WIDE RANGE OF VEHICLE DYNAMICS UNDER CONDITIONS OF VISUAL CUES ONLY, ROLL-MOTION CUES ONLY, AND SIMULTANEOUS VISUAL AND ROLL-MOTION CUES. ADDITION OF ROLL MOTION CUES TO VISUAL CUES PERMITS THE HUMAN OPERATOR TO INCREASE HIS PHASE LEAD AT FREQUENCIES ABOVE 2 RAD/SEC, THEREBY ALLOWING HIGHER GAIN AND CROSSOVER FREQUENCY AND REDUCED TRACKING ERROR.

SHWALTER, T.W. AND MILLER, R.J. G-SEAT SYSTEM STEP INPUT AND SINUSOIDAL RESPONSE CHARACTERISTICS. NASA AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA. NASA TM-78478, JUNE 1978.

* ABSTRACT *
THE STEP INPUT AND SINUSOIDAL RESPONSE CHARACTERISTICS OF A PNEUMATICALLY DRIVEN COMPUTER CONTROLLED G SEAT WERE EXAMINED IN THIS STUDY. THE RESPONSE DATA SHOW THAT THIS SYSTEM CAN BE MODELLED AS A FIRST ORDER SYSTEM WITH AN 0.08 SEC. TIME LAG AND A 0.53 SEC. TIME CONSTANT.

SIMPSON, R.G. AND COHEN, E. LINK DIVISION/SINGER COMPANY, BINGHAMTON, NEW YORK. FUTURE UNDERGRADUATE PILOT TRAINING (UPT) SYSTEM STUDY, PHASE II. SUMMARY REPORT. REPORT NO. LR 23918-2 SEPTEMBER 1970.

* ABSTRACT *
SIX REPORTS ARE INCLUDED IN THIS VOLUME. THESE REPORTS DOCUMENT RESEARCH CONDUCTED TO PROVIDE AN ASSESSMENT OF SIMULATION REQUIREMENTS AND TECHNOLOGY REQUIRED TO AID IN SELECTING CANDIDATE SYSTEMS FOR THE UPT 7590. THE APPROACH TO EACH STUDY WAS TO: RESEARCH THE LITERATURE AND SUMMARIZE CURRENT STATE OF THE ART TECHNOLOGY; PROJECT STATE OF THE ART IMPROVEMENTS TO THE 1975-1990 TIME FRAME; AND RECOMMEND CONCEPTS, SYSTEMS OR DEVICES FOR CONSIDERATION IN FUTURE UPT CANDIDATE SYSTEMS.

SINACORI, J.B. V/STOL GROUND-BASED SIMULATION TECHNIQUES. PREPARED BY NORTHROP CORP., NORAIR DIVISION, HAWTHORNE, CA FOR U.S. ARMY AVIATION MATERIAL LABORATORIES, FORT EUSTIS, VIRGINIA, USAAVLABS TECHNICAL REPORT 67-55, NOV. 1967.

* ABSTRACT *

A STUDY OF VARIOUS KINDS OF SIMULATORS HAS BEEN MADE TO DETERMINE THEIR CAPABILITY TO PRODUCE DATA REPRESENTATIVE OF VISUAL FLIGHT. FOUR SIMULATIONS OF A JET-LIFT V/STOL AIRCRAFT WERE CONDUCTED USING THE SAME PILOT. CONTROL CHARACTERISTICS AND AIRFRAME PARAMETERS WERE MAINTAINED CONSTANT (AS CLOSELY AS POSSIBLE), AND THE SAME TASKS WERE USED BY THE PILOT IN EACH EVALUATION. THE RESULTING DATA WERE COMPARED WITH FLIGHT RESULTS FROM THE SAME AIRCRAFT. THE SIMULATOR USED DIFFERENT DISPLAYS, MOTION MODES, AND INSTRUMENTATION, AND THE RESULTS ARE DISCUSSED IN THE LIGHT OF THE CHARACTERISTICS OF EACH SIMULATOR.

THE RESULTS SHOW CLEARLY THAT IN ORDER TO PRODUCE QUANTITATIVE DATA REPRESENTATIVE OF FLIGHT RESULTS, THE DISPLAY MUST HAVE A QUALITY LEVEL COMPATIBLE WITH THE TASK BEING PERFORMED. SPECIFICALLY, A PRECISION HOVERING TASK REQUIRES A HIGH RESOLUTION DISPLAY, WHILE A TRANSLATION (OR TRANSITION TASK) CAN BE PERFORMED WITH A DISPLAY OF MUCH LESS RESOLUTION. THE DISPLAY CONTENT IS IMPORTANT, PARTICULARLY FOR THE PRECISION HOVERING TASK WHERE HEIGHT HOLDING IS REQUIRED. FOR FLIGHT SIMULATION OF LARGE TRANSLATIONAL MOVEMENTS, COCKPIT MOTION DID NOT APPEAR TO AFFECT THE RESULTS, HOWEVER, FOR PRECISION HOVER AND SMALL, QUICK POSITION CHANGES, COCKPIT MOTION APPEARS TO BE IMPORTANT IN THAT IT ASSISTS THE PILOT IN DETECTING SMALL DRIFT AND IMPROVES HIS ABILITY TO CONTROL VEHICLE ATTITUDE. THE ABSENCE OF COCKPIT MOTION WHEN USING A POINT SOURCE VISUAL DISPLAY FOR THE PRESENTATION OF VISUAL INFORMATION CAN CAUSE VERTIGO AND LOSS OF PERFORMANCE. THE STUDY SHOWS THAT VALID V/STOL FLIGHT SIMULATION CAN BE ACCOMPLISHED AND THAT QUANTITATIVE AND SUBJECTIVE DATA WHICH CLOSELY COMPARE WITH FLIGHT RESULTS CAN BE OBTAINED.

SINACORI, J.B. 'VALIDATION OF GROUND BASED SIMULATION'. PAPER PRESENTED AT A MEETING OF THE AMERICAN HELICOPTER SOCIETY, 1969.

* ABSTRACT *

A STUDY OF VARIOUS KINDS OF SIMULATORS HAS BEEN MADE TO DETERMINE THEIR CAPABILITY TO PRODUCE DATA REPRESENTATIVE OF VISUAL FLIGHT. FIVE SIMULATIONS OF A SMALL JET LIFT V/STOL AIRCRAFT WERE CONDUCTED USING THE SAME RESEARCH PILOT. CONTROL RESPONSE AND AIRCRAFT PARAMETERS WERE MAINTAINED CONSTANT IN EACH SIMULATION. THE RESULTING DATA WERE COMPARED WITH FLIGHT RESULTS FROM THE SAME AIRCRAFT AND PILOT. THE SIMULATORS USED DIFFERENT DISPLAYS, MOTION MODES AND INSTRUMENTATION AND THE RESULTS ARE DISCUSSED IN THE LIGHT OF THE CHARACTERISTICS OF

EACH SIMULATOR AND THE AIRCRAFT. BECAUSE OF THE AVAILABILITY OF FLIGHT DATA, ONLY TWO TASKS WERE STUDIED IN DETAIL, THE PRECISION HOVER, AND THE LATERAL QUICK START AND STOP MANEUVER.

A VALIDATION RATIONALE WAS DEVELOPED TO ASSIST THE PILOT IN HIS EVALUATIONS. IT USED RANDOM DATA ANALYSIS TECHNIQUES TO ESTABLISH DYNAMIC EQUIVALENCE BETWEEN A VEHICLE AND A SIMULATION OF THAT VEHICLE. AN EXAMPLE OF ITS USE IS PRESENTED TOGETHER WITH A DISCUSSION OF ITS LIMITATIONS. SUGGESTIONS FOR FUTURE TESTING ARE ALSO INCLUDED.

ONE PROMISING TYPE OF SIMULATOR WAS STUDIED IN GREATER DETAIL. IT EMPLOYS THE POINT LIGHT SOURCE PROJECTION PRINCIPLE TO PRODUCE A CONTACT DAY SCENE AND EMPLOYS A ROTATIONAL MOTION BASE. A MOTION BASE-VISUAL DISPLAY DRIVE MECHANISM WAS DESIGNED FOR THIS SIMULATOR WHICH IS BELIEVED COMPATIBLE WITH THE SENSORY DYNAMICS OF THE HUMAN. THE VALIDATION RATIONALE WAS USED TO DETERMINE THE BEST CONSTANTS OF THIS MECHANIZATION FOR THE TASKS STUDIED. OPERATION OF THIS SIMULATOR FIXED BASE INDUCES PILOT NAUSEA AND REDUCES PILOT-VEHICLE PERFORMANCE. USE OF THE MOTION SYSTEM, HOWEVER, GREATLY REDUCES OR IN MOST CASES, ELIMINATES THE NAUSEA AND PRODUCES RESULTS WHICH COMPARE FAVORABLY WITH FLIGHT RESULTS WHEN THE CONSTANTS OF THE DRIVE MECHANIZATION ARE SET PROPERLY. THE EFFECTS OF MOTION ARE DISCUSSED INCLUDING THE EFFECTS OF FALSE MOTION CUES.

PILOT HEAD MOVEMENTS, DURING MOVING BASE OPERATIONS FOR THE TASKS STUDIED, WERE FOUND TO BE RELATED TO THE VEHICLE MOTIONS. SIMILAR HEAD MOVEMENTS WERE FOUND IN FLIGHT WITH A HELICOPTER. HEAD MOVEMENTS IN THE SIMULATOR DURING FIXED BASE OPERATION WERE DIFFERENT. AN EXPLANATION IS OFFERED BASED ON THE EYE COUNTERROLL REFLEX AND CERTAIN CONCEPTS OF HUMAN SPATIAL ORIENTATION.

A DISCUSSION OF A SIMULATION FOR A LARGE CARGO HELICOPTER DURING LE-AND-AWAY OPERATIONS IS INCLUDED WHICH SHOWS SOME EFFECTS OF VEHICLE SIZE. THE BASIC PRINCIPLES USED IN THE DESIGN OF THE POINT LIGHT SOURCE SIMULATOR MECHANIZATION WERE ALSO EMPLOYED IN THIS SIMULATION. THE SIMULATOR IS CAPABLE OF PRODUCING LINEAR AS WELL AS ROTATIONAL MOTIONS HOWEVER, AND THE LINEAR MOTIONS ARE VITAL TO THE EFFECTIVE SIMULATION OF THIS VEHICLE BECAUSE THE PILOT STATION IS CONSIDERABLY FORWARD OF THE CENTER OF GRAVITY.

THE BASIC ADVANTAGES AND LIMITATIONS OF THE SIMULATORS STUDIED ARE DISCUSSED AND SUGGESTIONS FOR FUTURE RESEARCH ARE GIVEN.

SINACHRI, W.B. A PRACTICAL APPROACH TO MOTION SIMULATION., AIAA PAPER 73-931, AIAA VISUAL AND MOTION SIMULATION CONFERENCE, PALO ALTO, CA, SEPT. 10-12, 1973.

* ABSTRACT *

A MOTION DRIVE METHOD IS PRESENTED WHICH OFFERS THE SIMULATOR USER A MEANS FOR RAPIDLY DESIGNING AN EFFECTIVE MOTION DRIVE LOGIC. PROCEDURES AND ROUTINES FOR ADAPTING THIS METHOD TO ANY TYPE OF MOTION BASE ARE ALSO INCLUDED TOGETHER WITH DESIGN CHARTS, TABLES AND RELATED DATA WHICH CAN BE USED TO ESTIMATE AN INITIAL SET OF COEFFICIENTS. USER TECHNIQUES ARE THEN PRESENTED WHICH RELATE THE LOGIC SCHEME TO THE MOTION BASE TYPE WITH CONSIDERATION OF DATA FROM HUMAN MOTION PERCEPTION LITERATURE. REFINEMENT PROCEDURES ARE GIVEN WITH SOME EXPERIMENTAL DATA FROM SIMULATIONS OF FIGHTERS, STOL TRANSPORTS, AND LARGE HELICOPTERS. THE MATERIAL IS ORGANIZED SO AS TO BE USEFUL AS BOTH A COMPUTER PROGRAMMERS MANUAL AND A BRIEF USER'S GUIDE.

SINACORI, J.B. A BRIEF SURVEY OF MOTION SIMULATORS' DRIVE LOGIC WITH EMPHASIS ON THE ROLL AXIS. SYSTEMS TECHNOLOGY, INC., STI WORKING PAPER NO. 1094-2, MAY 1977.

* ABSTRACT *

A DOZEN REFERENCES WERE SELECTED FOR REVIEW WHICH PRESENTED EXPERIMENTAL RESULTS FOR THE 'PERCEPTUAL FIDELITY' QUESTION. THE DRIVE LOGIC SURVEY WAS SUMMARIZED AS FOLLOWS:

ROLL MOTION IMPROVES PILOT PERFORMANCE PARTICULARLY WHEN TASK LOADING IS INCREASED.

TILT CUE (GRAVITATIONAL REACTION COMPONENT) FURTHER IMPROVES PILOT PERFORMANCE.

SPURIOUS APPEARING SIDE FORCE CUES CAN GIVE TENDENCIES TOWARD DISORIENTATION.

ROLL MOTION SCALING HAS A SIGNIFICANT EFFECT ON PILOT PERFORMANCE.

WASHOUT HAS A MINOR EFFECT ON PILOT ROLL TRACKING PERFORMANCE.

ROLL WASHOUT CAN BE USED TO SUPPRESS THE TILT CUE BUT 'QUICK' WASHOUTS CAUSE DISORIENTATION.

MISCOORDINATION OF SIDE FORCE CAN BE USED TO REDUCE SWAY TRAVEL REQUIREMENTS.

SKANS, S. THE SPECIFICATION OF REQUIREMENTS FOR FLIGHT SIMULATION. PROCEEDINGS OF THE ROYAL AERONAUTICAL SOCIETY SYMPOSIUM 'THEORY AND PRACTICE IN FLIGHT SIMULATION', LONDON, ENGLAND, APRIL, 1976.

* ABSTRACT *

THE SIMULATOR USED FOR RESEARCH, DEVELOPMENT OF TRAINING IS A PECULIAR TOOL IN AT LEAST ONE RESPECT. IT SHOULD BE MORE ADVANCED THAN ITS COUNTERPART AIRCRAFT. NORMALLY IT CONSISTS OF SIX OR SEVEN SUBSYSTEMS. THIS PAPER DEALS WITH SOME CRITERIA AND SPECIFICATIONS FOR TWO OF THESE MOTION AND VISUAL SYSTEMS.

SMITH, G.F. AND DE ROCHER, W.L., JR. A FULL-SCALE SIX-DEGREE-OF-FREEDOM, ORBITAL CLOSURE AND DOCKING SIMULATOR. MARTIN COMPANY, REPORT M-63-134, AEROSPACE DIVISION OF MARTIN-MARIETTA CORP., DENVER, COLORADO, JULY 1963.

* ABSTRACT *

THE NEED FOR A CLOSURE AND DOCKING SIMULATOR AS DISTINCT FROM A RENDEZVOUS SIMULATOR IS CONSIDERED, AND THIS TYPE OF SIMULATOR IS SHOWN TO BE DESIRABLE. REQUIREMENTS FOR A CLOSURE AND DOCKING SIMULATOR ARE PRESENTED ALONG WITH APPROACHES THAT MIGHT BE USED FOR DESIGN. IT IS SHOWN THAT A COMBINATION SIMULATOR OF A COMPUTING MACHINE AND A SERVO-DRIVEN MECHANICAL SYSTEM IS THE BEST CHOICE. DETAIL SPECIFICATIONS AND A DESCRIPTION OF A COMBINATION SIMULATOR THAT HAS BEEN CONSTRUCTED IN DENVER ARE PRESENTED ALONG WITH A SERIES OF POSSIBLE MODIFICATIONS AND EXTENSIONS OF THE BASIC SYSTEM. THE PAPER CONCLUDES WITH A DISCUSSION OF THE SIGNIFICANCE OF THIS TYPE OF SIMULATION IN THE DEVELOPMENT OF SPACE RENDEZVOUS. (AUTHOR)

SMITH, F. HUMAN DESCRIBING FUNCTIONS MEASURED IN FLIGHT AND ON SIMULATORS, SECOND ANNUAL NASA UNIVERSITY CONFERENCE ON MAN-MADE CONTROL, NASA-SP-128, FEBRUARY, 28-MARCH 2, 1966 PP.279-290.

* ABSTRACT *

COMPARISONS HAVE BEEN MADE BETWEEN HUMAN DESCRIBING FUNCTIONS MEASURED IN FLIGHT AND ON THE GROUND USING TWO DIFFERENT TYPES OF GROUND SIMULATION. A T-33 VARIABLE-STABILITY AIRPLANE WAS USED FOR THE IN-FLIGHT MEASUREMENTS. THE GROUND TESTS WERE CONDUCTED IN THE T-33 AIRPLANE ON THE GROUND WITH SIMULATED INSTRUMENT FLIGHT AND ALSO ON A GENERAL-PURPOSE ANALOG COMPUTER IN CONJUNCTION WITH A CONTACT ANALOG DISPLAY. FOR THIS STUDY, A MULTIPLE-DEGREE-OF-FREEDOM CONTROLLED ELEMENT WAS USED IN A SINGLE-LOOP COMPENSATORY TRACKING TASK. THE INPUT DISTURBANCE IN EACH CASE CONSISTED OF THE SUM OF 10 SINE WAVES WITH A CUTOFF FREQUENCY OF 1.5 RADIAN PER SECOND.

A DIGITAL COMPUTER WAS USED TO ANALYZE THE DATA, WHICH WERE STORED ON MAGNETIC TAPE. THE POWER SPECTRA AND CROSS SPECTRA USED TO COMPUTE THE DESCRIBING FUNCTIONS WERE DETERMINED FROM FOURIER TRANSFORMS OF THE TIME HISTORIES. BY ELIMINATING THE NEED TO STORE ALL THE DATA IN THE COMPUTER AS IS REQUIRED WHEN

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COMPUTING AUTOCORRELATION FUNCTIONS, IT WAS POSSIBLE TO PROCESS CONSIDERABLY MORE DATA POINTS PER RUN, THEREBY INCREASING THE ACCURACY OF THE RESULTS.

THE RESULTS OF THIS INVESTIGATION INDICATE NO SIGNIFICANT DIFFERENCE BETWEEN THE AVERAGE DESCRIBING FUNCTIONS MEASURED IN FLIGHT AND THOSE MEASURED IN A FIXED-BASE SIMULATOR. HOWEVER THE VARIANCE WAS FOUND TO BE CONSIDERABLE IN THE FLIGHT DATA. THE SYSTEM OPEN-LOOP DESCRIBING FUNCTIONS MEASURED IN THE FIXED-BASE SIMULATOR AGREED WELL WITH THE RESULTS OF AN INVESTIGATION BY MORLER IN WHICH THE TRACKING TASK LINEAR COHERENCE WAS ALSO CLOSE TO THE VALUES FOUND IN THIS SAME INVESTIGATION. ALTHOUGH CONTRARY TO THE RESULTS OF PREVIOUS INVESTIGATIONS, THE LINEAR-CORRELATION FUNCTION P WAS ALWAYS EQUAL TO 1.

SMITH, J.F., FLEXMAN, R.E. AND HOUSTON, R.C.
DEVELOPMENT OF AN OBJECTIVE METHOD OF RECORDING FLIGHT PERFORMANCE. AIR TRAINING COMMAND HUMAN RESOURCES RESEARCH CENTER, TECHNICAL REPORT 52-15 LACKLAND AFB, SAN ANTONIO, TEXAS, DECEMBER, 1952.

* ABSTRACT *

THIS PROJECT WAS PART OF A GENERAL RESEARCH PROGRAM PROPOSED DURING AN AIR FORCE PLANNING CONFERENCE ON PILOT TRAINING RESEARCH. THE PURPOSE OF THIS PROJECT WAS TO DEVELOP A METHOD OF OBJECTIVELY RECORDING PILOT PERFORMANCE IN THE PRIMARY FLYING TRAINING PROGRAM.

TO CONSTRUCT FORMS FOR RECORDING STUDENT PILOT PERFORMANCE SATISFACTORILY, IT FIRST WAS NECESSARY TO DETERMINE THE REQUIREMENTS FOR COMPLETION OF THE FLYING PHASE OF PRIMARY PILOT TRAINING. THE APPROACH TO THIS TASK WAS TO EXAMINE ALL MANEUVERS IN THE PRIMARY FLYING SYLLABUS IN TERMS OF THEIR COMPONENT ITEMS. EACH MANEUVER AND ITS COMPONENT ITEMS WAS DESCRIBED AND LISTED IN AN ITEM-BY-ITEM FORMAT. FOLLOWING IN-FLIGHT CHECKS, THE MANEUVER ANALYSES WERE REVISED TO INCREASE THEIR ACCURACY AND COMPLETENESS.

UPON COMPLETION OF THE MANEUVER ANALYSIS, PERFORMANCE RECORD SHEETS WERE DESIGNED TO RECORD STUDENT PERFORMANCE IN FLIGHT. ITEMS FOR THESE RECORD SHEETS WERE SELECTED FROM THE MANEUVER ANALYSIS. EXPERIENCED FLIGHT INSTRUCTORS REVIEWED, USED, AND REVISED THE PERFORMANCE RECORD SHEETS. IN ADDITION, OBSERVER RELIABILITY STUDIES WERE CONDUCTED TO DETERMINE THE AGREEMENT BETWEEN THE RECORDS OF TWO INSTRUCTORS OBSERVING THE SAME PILOT PERFORMANCE. RESULTS FROM THESE STUDIES WERE EMPLOYED TO REVISE THE PERFORMANCE RECORD SHEETS FOR MAXIMUM OBSERVER RELIABILITY.

THERE ARE TWO DIRECT PRODUCTS OF THIS RESEARCH: FIRST, THE MANEUVER ANALYSIS COVERING ALL MANEUVERS IN THE PRIMARY PILOT TRAINING PROGRAM, AND SECOND, A METHOD OF OBJECTIVELY RECORDING

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PILOT PERFORMANCE. THESE TWO PRODUCTS WILL BE OF USE IN PILOT TRAINING FOR STANDARDIZATION, FOR THE COMPARISON OF GROUP PERFORMANCE, AND FOR THE DEVELOPMENT OF OBJECTIVE PROFICIENCY MEASURES.

THE RESEARCH REPORTED REPRESENTS THE FIRST TIME THAT THE TASK OF A MILITARY PILOT TRAINEE HAS BEEN MINUTELY DESCRIBED AND ACTUAL PERFORMANCE OBJECTIVELY RECORDED FOR BOTH CONTACT AND INSTRUMENT MANEUVERS. THE APPROACH USED TO DEVELOP THE PERFORMANCE RECORD SHEETS, AS WELL AS THEIR UTILIZATION WILL BE APPLICABLE TO MANY AREAS OF PILOT TRAINING RESEARCH.

R.L. SMITH ET AL - ROUGH AIR SIMULATING MEANS FOR GROUNDED AVIATION TRAINERS
PATENT NO. 2,787,842
FILED DEC. 7, 1951 GRANTED APRIL 9, 1957

NO ABSTRACT

SPACE, A.F. HUMAN FACTORS INPUTS TO THE TRAINING DEVICE DESIGN PROCESS. NAVTRADEVCE 69-C-0298-1. U.S. NAVAL TRAINING DEVICE CENTER, ORLANDO, FLORIDA, SEPTEMBER 1971.

* ABSTRACT *

THIS REPORT PRESENTS GUIDELINES FOR ACHIEVING HUMAN FACTORS INPUTS TO THE DESIGN OF SYNTHETIC TRAINING SYSTEMS. IT PROVIDES A METHOD FOR DESIGN AND ORGANIZED TRAINING CONCEPTS AND DATA SUPPORTIVE TO THE HUMAN FACTORS SPECIALIST IN DERIVING THE FUNCTIONAL SPECIFICATIONS FOR THE DESIGN OF ANY COMPLEX TRAINING DEVICE.

THREE MAJOR SECTIONS ARE PROVIDED. THE FIRST OF THESE PRESENTS AN ORGANIZED METHOD FOR ACHIEVING HUMAN FACTORS INPUTS TO THE TRAINING SYSTEM DESIGN.

ANOTHER SECTION PRESENTS CONCEPTS AND DATA APPLICABLE TO THE DESIGN OF TRAINING DEVICES. SEVEN CONTENT CHAPTERS ARE SUBSUMED UNDER THIS SECTION. THESE ARE (1) VISUAL SIMULATION, (2) PLATFORM MOTION SIMULATION, (3) VEHICLE CONTROL REQUIREMENTS, (4) INFORMATION PROCESSING REQUIREMENTS, (5) MEASUREMENT SYSTEM DESIGN, (6) ADAPTIVE TRAINING STRATEGIES AND (7) DELIBERATE DEPARTURES FROM REALISM IN DESIGN. FOR EACH CHAPTER, CONCEPTS AND DATA WHICH PROVIDE HUMAN FACTORS DESIGN SUPPORT ARE ARTICULATED BASED ON REVIEW OF THE PERTINENT LITERATURE. WHERE DESIGN EVIDENCE IS MEAGER, THE DATA GAPS ARE IDENTIFIED. RESEARCH ISSUES OF HIGH PRIORITY FOR HUMAN FACTORS DESIGN ARE RECOMMENDED.

THE SECTION ON MOTION SIMULATION (2) IS ORGANIZED AS FOLLOWS:

AN ELEMENTAL REVIEW OF THE MOTION FORCES PERTINENT TO THE SIMULATED ENVIRONMENT IS PROVIDED.

A REVIEW OF THE LITERATURE IS PRESENTED FOR THE PURPOSE OF PLACING INTO PERSPECTIVE THE UTILITY OF MOVING BASE SIMULATION FOR TRAINING EFFECTIVENESS.

MOTION REQUIREMENTS RELATIVE TO TRAINING DEVICE DESIGN ARE ORGANIZED.

SPECIFICATIONS FOR THE INCORPORATION OF MOTION INTO GROUND-BASED TRAINING DEVICES ARE PRESENTED TO THE EXTENT OF THE DATA AVAILABLE.

SMOCE, A.F. THE FIDELITY ISSUE: HOW MUCH LIKE OPERATIONAL SYSTEMS SHOULD THEIR TRAINING DEVICE COUNTERPARTS BE IN COMMENSURATIVE TECHNICAL JOURNAL, NAVAL TRAINING DEVICE CENTER 25TH ANNIVERSARY. NAVTRADEVEN IH-223 NOVEMBER 1971. T-5318

* ABSTRACT *

KNOWLEDGEABLE, WELL MEANING PEOPLE BELIEVE DIFFERENT THINGS ABOUT FIDELITY OF SIMULATION. THIS PAPER EXPLORES THE MEANINGS AND THE IMPLICATIONS OF THE VARIOUS POSITIONS ON FIDELITY OF SIMULATION.

DISCUSSED ARE THREE AREAS, RELATIVE TO INSTALLING THE ENVIRONMENT, IN WHICH TRAINING WILL BE ACCOMPLISHED. THESE ARE: (1) THE MAIN ISSUE, SUFFICIENT FIDELITY TO ENSURE TRANSFER OF TRAINING, (2) LEVELS OF FIDELITY TO DEVICE DESIGN AND (3) DETERMINING THE FIDELITY REQUIREMENTS FOR TRAINING AS A FUNCTION OF TRAINING PURPOSE, TASK STRUCTURE AND TRAINER POPULATION.

REGARDING SIMULATION TECHNOLOGY, KEY ISSUES IN TRAINING DEVICE DESIGN ARE EXPLORED.

MOTION IS DISCUSSED AS IT EXEMPLIFIES DESIGN SITUATIONS WHERE THE ENGINEERING TECHNOLOGY IS NOT FULLY ABLE TO REPRESENT CERTAIN EVENTS WITH THE REALISM REQUIRED FOR EFFECTIVE INSTRUCTION. IN THE CASE OF MOTION SIMULATION, TECHNIQUES ARE REQUIRED FOR DECEIVING THE HUMAN WITH CUES THAT HAVE SIGNAL VALUE AND RELEVANCE TO THE REAL-WORLD COUNTERPART. ACCELERATION ONSET CUES, WASHOUT ACCELERATION, THE SCALING OF ACCELERATION, AND THE USE OF SIGNALING TECHNIQUES SUCH AS INFLATABLE SEAT CUSHIONS AND SEAT BELT TIGHTENERS ARE EXAMPLES.

SMOCE, A.F., GRUBER, A. AND ELY, J.H. HUMAN FACTORS TECHNOLOGY IN THE DESIGN OF SIMULATORS FOR OPERATOR TRAINING. U.S. NAVAL

NAVTRAEGUIPCEN IH-298

TRAINING DEVICE CENTER TECHNICAL REPORT: NAVTRADEVCCEN 1103-1,
18 DEC. 1963.

* ABSTRACT *

THIS REPORT PRESENTS AN ORGANIZED BODY OF INFORMATION USEFUL FOR DEALING WITH THOSE HUMAN FACTORS PROBLEMS FREQUENTLY ENCOUNTERED IN THE DEVELOPMENT OF THE WEAPONS SYSTEM TRAINER. EMPHASIS IS GIVEN THROUGHOUT TO THE GENERAL PROBLEMS INVOLVED IN DEVELOPING THE COMPLETE TRAINING SYSTEM RATHER THAN TO THE ANALYSIS OF DETAILS SPECIFIC TO GIVEN TRAINING SYSTEMS. IT SUMMARIZES BASIC HUMAN FACTORS INFORMATION WHICH INFLUENCES THE DESIGN AND CONSTRUCTION OF TRAINING DEVICES. SUCCESSIVE CHAPTERS OF THE REPORT ARE DEVOTED TO DETERMINING TRAINING NEEDS, DEVELOPING THE ENVIRONMENT FOR LEARNING, UNDERSTANDING SIMULATION REQUIREMENTS FOR TRAINING, DEVELOPING A MEASUREMENT CAPABILITY, AND DISCUSSING THE HUMAN ENGINEERING PROBLEMS IN TRAINER DESIGN. AS IT PROVIDES A CONSIDERABLE BACKGROUND OF HUMAN FACTORS INFORMATION PERTINENT TO THE SYNTHETIC GROUND ENVIRONMENT, THIS REPORT WILL BE OF INTEREST TO INDIVIDUALS DIRECTLY CONCERNED WITH WEAPONS SYSTEM TRAINING PROGRAMS, PREPARING TRAINER SPECIFICATIONS, DEVELOPING TRAINING STANDARDS, AND TESTING AND EVALUATING SIMULATION EQUIPMENT.

CHAPTER IV, (SIMULATION), THE MAJOR PORTION OF WHICH WAS PREPARED BY DR. CHARLES R. KELLEY OF DUNLAP AND ASSOCIATES, INC., INCLUDES AN INTERESTING SECTION ON MOTION. A GOOD ILLUSTRATION OF THE EFFECT ON HEAD MOTION OF A CHANGE IN LOCATION OF THE ROLL AXIS FROM ABOVE TO BELOW THE HEAD, IS PROVIDED. IT IS SHOWN THAT AT THE HIGHLY IMPORTANT INSTANT WHEN A MANEUVER BEGINS, THE HEAD IS TRANSLATED TO THE LEFT IN ONE CASE, TO THE RIGHT IN THE OTHER CASE FOR THE SAME MANEUVER. THIS STRESSES THE IMPORTANCE OF LOCATING THE AXES OF ROTATION IN THE SIMULATOR TO A REASONABLE APPROXIMATION OF THAT IN THE AIRCRAFT IF FIDELITY IS TO BE MAINTAINED.

SMOKE, A.F., HALL, E.R. AND MEYER, D.E. (AN ASSESSMENT OF RESEARCH RELEVANT TO PILOT TRAINING). AMRL-TR-66-196. AEROSPACE MEDICAL RESEARCH LABORATORIES, WRIGHT-PATTERSON AFB, OHIO, NO. VEMBER 1966.

* ABSTRACT *

THIS REPORT PRESENTS A CRITICAL REVIEW AND INTERPRETATION OF THE CONSIDERABLE AMOUNT OF RESEARCH DATA THAT HAVE EITHER DIRECT OR INDIRECT IMPLICATIONS FOR THE TRAINING OF PILOTS. THE PURPOSE IS TO ORGANIZE SYSTEMATICALLY THE RESEARCH FINDINGS FROM THE HUMAN PERFORMANCE AND THE TRAINING RESEARCH LITERATURE THAT ARE PERTINENT TO PILOT TRAINING, AND BASED ON THE STATUS OF RESEARCH IN DEFINED AREAS, TO IDENTIFY RESEARCHABLE ISSUES. SUCCESSIVE PORTIONS OF THE REPORT DEAL WITH STUDIES ON THE DEFINITION OF THE PILOTS JOB, THE ACQUISITION OF FLYING SKILLS,

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PERFORMANCE MEASUREMENT, SIMULATION AND TRANSFER OF TRAINING, OPERATIONAL COMPONENTS OF THE PILOT'S JOB, AND THE MAINTENANCE OF FLYING PROFICIENCY. IN ADDITION, ATTENTION IS GIVEN TO STUDIES CONCERNING IMPROVING TRAINING SYSTEMS AND RECENT INNOVATIONS IN TRAINING METHODS ARE REVIEWED. AS IT PROVIDES A CONSIDERABLE BACKGROUND OF INFORMATION DIRECTLY CONCERNED WITH PILOT TRAINING, THIS REPORT WILL BE OF INTEREST TO INDIVIDUALS INVOLVED IN ANY ASPECT OF FLIGHT TRAINING.

SMODE, A.F. AND HALL, E.R.
TRANSLATING INFORMATION REQUIREMENTS INTO TRAINING DEVICE FIDELITY REQUIREMENTS. IN PROCEEDINGS HUMAN FACTORS SOCIETY 19TH ANNUAL MEETING, HUMAN FACTORS SOCIETY, SANTA MONICA, CA 1975.

* ABSTRACT *

THE FAILURE OF TRAINING EQUIPMENT TO MEET TRAINING NEEDS IS FREQUENTLY ATTRIBUTED TO POOR ENGINEERING FIDELITY. INACCURATE OR INADEQUATE INFORMATION REQUIREMENTS MAY BE EQUALLY RESPONSIBLE FOR SHORTCOMINGS IN DEVICE DESIGN. SOME OBSERVATIONS AND VIEWS ON FIDELITY ISSUES AND ON ACHIEVING FIDELITY REQUIREMENTS ARE OFFERED.

SAE COMMITTEE AG-3
A SURVEY REPORT OF SIMULATORS USED AS TOOLS FOR RESEARCH, DESIGN AND DEVELOPMENT.
SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
AEROSPACE INFORMATION REPORT AIR 779, JUNE 20, 1964.
L64-1765

* ABSTRACT *

THIS REPORT SUMMARIZES THE RESULTS OF A SURVEY REGARDING THE USE OF SIMULATORS AS TOOLS FOR RESEARCH, DESIGN, AND DEVELOPMENT IN AEROSPACE ACTIVITIES.

QUESTIONNAIRES DISTRIBUTED TO 168 COMPANIES RESULTED IN 70 REPLIES. THE INFORMATION RECEIVED AND AS PRESENTED IN THIS REPORT COMPRISES VOLUNTARY AND UNAIDED RESPONSES. NO ATTEMPT WAS MADE TO DRAW INFERENCES OR TO SEEK CLARIFICATION OR EXPANSION OF THE DATA. THE ANALYSIS PERFORMED WAS FOR COMPILATION RATHER THAN INTERPRETATION OR COMPARISON.

INCLUDED IS INFORMATION ON THE PHYSICAL MOTION, IF ANY, PRODUCED BY THE SIMULATORS, THE COMPUTER CAPABILITY FOR MOTION SIMULATION AND OTHER VISUAL/MOTION CAPABILITY INFORMATION.

SOLARZ, A.K., MATHENY, W.G., DOUGHERTY, D.J. AND HASLER, S.G.
THE EFFECT OF ATTITUDE TOWARD LINK TRAINING UPON PERFORMANCE
IN THE AIRCRAFT. MEMO REPORT D-12, TASK D, CONTRACT NO. AF
33 (C38) - 25726, UNIVERSITY OF ILLINOIS, SEPT, 1953.

* ABSTRACT *

THE EXPERIMENT WAS DESIGNED TO DISCOVER THE EFFECT OF A POSITIVE OR NEGATIVE ATTITUDE TOWARD THE P-1 LINK UPON TRANSFER OF TRAINING TO THE T-6 AIRCRAFT. AN ATTITUDE SCALE WAS CONSTRUCTED TO MEASURE THE TRAINEE'S ATTITUDE TOWARD THE P-1 LINK. TWO EXPERIMENTAL GROUPS WERE USED: IN ONE GROUP, A POSITIVE ATTITUDE TOWARD THE LINK TRAINER WAS INDUCED AND IN THE OTHER GROUP A NEGATIVE ATTITUDE. A CONTROL GROUP PRACTICED ONLY ON THE T-6 AIRCRAFT. PERFORMANCE WAS MEASURED IN BOTH THE LINK AND THE T-6 AIRCRAFT IN TERMS OF TRIALS TO REACH A CRITERION. SINCE ONLY A SMALL NUMBER OF SUBJECTS WAS USED, ONLY THE TRENDS APPARENT IN THE RAW DATA ARE DISCUSSED. THE GROUP WITH THE FAVORABLE ATTITUDE TOWARDS THE LINK REACHED CRITERION IN THE LINK IN FEWER TRIALS; THIS RESULT WAS REVERSED IN THE T-6 AIRCRAFT. POSITIVE TRANSFER FROM LINK TO AIRCRAFT TAKES PLACE REGARDLESS OF THE TRAINEE'S ATTITUDE TOWARD THE LINK AND APPEARS TO BE DIRECTLY RELATED TO TOTAL TIME SPENT IN LINK TRAINING.

SOLIDAY, S.M. EFFECTS OF TASK LOADING ON PILOT PERFORMANCE DURING SIMULATED LOW-ALTITUDE, HIGH SPEED FLIGHT. USATRECOM TR 64-69, ASTIC C16448, FEBRUARY 1965.

* ABSTRACT *

THE EFFECTS OF TASK LOADING ON PILOT PERFORMANCE DURING SIMULATED LOW-ALTITUDE, HIGH-SPEED FLIGHT WERE STUDIED. APPROXIMATELY 210 HOURS OF FLIGHT WERE MADE BY EXPERIENCED PILOT PILOTS IN A MOVING-BASE SIMULATOR THAT HAD A TOTAL VERTICAL TRAVEL OF 12 FEET AND AN ACCELERATION CAPABILITY OF $\pm 6G$. THE FLIGHTS WERE MADE OVER SEVERAL TYPES OF TERRAIN AT SEVERAL AIRSPEEDS UNDER DIFFERENT CONDITIONS OF NAVIGATION TASK AND EMERGENCY TASK LOADING. MEDIUM-HEAVY TURBULENCE WAS SIMULATED FOR ALL FLIGHTS. DATA WERE ANALYZED IN TERMS OF HUMAN PERFORMANCE ASPECTS OF THE MISSIONS.

SOLL, C.W. - FLIGHT TRAINER
PATENT NO. 2,524,238
FILED NOV. 15, 1946 GRANTED OCT. 3, 1950

NO ABSTRACT

SPARR, E. AND GALLOWAY, R.T. FLIGHT FIDELITY EVALUATION OF THE S-3A WEAPON SYSTEMS TRAINER, DEVICE 2F92, WITH THE VITAL III VISUAL SYSTEM, DEVICE 2B34A. 'NAVAL AIR TEST CENTER REPORT' AT-33R-76, NAS, PATUXENT RIVER, MARYLAND, 22 JULY 1976.

* ABSTRACT *

THE NAVAL AIR TEST CENTER (NATC) PARTICIPATED IN FINAL ACCEPTANCE TESTING OF THE S-3A WEAPON SYSTEMS TRAINER, DEVICE 2F92, WITH THE VITAL III (VIRTUAL IMAGE TAKEOFF AND LANDING) VISUAL SYSTEM AT NAS CECIL FIELD. APPROXIMATELY 10 HOURS OF COCKPIT TIME WERE UTILIZED IN DEVICE 2F92, UNIT 2, TO EVALUATE FLYING QUALITIES AND PERFORMANCE FIDELITY OF DEVICE 2F92, AND TO EVALUATE OVERALL FLIGHT FIDELITY OF THE DEVICE 2F92/VITAL III COMBINATION. INITIAL EVALUATION RESULTS INDICATED THAT THE OVERALL FLIGHT FIDELITY WAS UNSATISFACTORY. IN PARTICULAR, THE APPROACH AND LANDING TASK WAS CHARACTERIZED BY SLUGGISH RESPONSE IN THE PITCH AND ROLL AXES, HEAVY LONGITUDINAL CONTROL FORCES, AND DELAYED, JERKY INITIAL RESPONSE OF THE VISUAL SCENE TO PILOT CONTROL INPUTS. AS A RESULT OF MODIFICATIONS AND PATCHES DEVELOPED FOR THE DEVICE 2F92 CONTROL SYSTEM AND VITAL III SOFTWARE MODIFICATIONS AND PATCHES, THE FLIGHT FIDELITY OF DEVICE 2F92 WITH THE VITAL III IS SATISFACTORY TO DEVELOP AND MAINTAIN PILOT AIRMANSHIP SKILLS AND IS ESPECIALLY EFFECTIVE IN TRAINING FOR THE APPROACH AND LANDING TASK. EIGHT PART II DEFICIENCIES WHICH SHOULD BE CORRECTED AS SOON AS PRACTICABLE WERE IDENTIFIED DURING THIS EVALUATION. NATC EVALUATION OF DEFICIENCY CORRECTIONS SHOULD BE CONDUCTED DURING ACCEPTANCE TESTING OF DEVICE 2F92, UNIT 3. (AUTHOR)

SPITZER, R.E. AND RUMSEY, P.C. (PRELIMINARY REPORT ON WORK AT NASA-AMES SIX DEGREE OF FREEDOM MOTION SIMULATOR FACILITY). UNPUBLISHED BOEING COMPANY DOCUMENT, 1966.

* ABSTRACT *

FROM THE TEST RESULTS AND THE PILOT'S COMMENTS SOME GROUND RULES MAY BE TENTATIVELY SUGGESTED FOR DETERMINING THE PHYSICAL REQUIREMENTS OF A MOTION SYSTEM WHICH WILL GIVE A SUFFICIENT ACCELERATION CUE ON THE EVENT OF AN ENGINE FAILURE.

1. THE WASH OUT TIME CONSTANT SHOULD BE CHOSEN TO ENSURE THAT NO AMPLITUDE LIMITS ARE REACHED BEFORE THE PILOT HAS TIME TO INTRODUCE HIS CORRECTIVE ACTION.

2. EVERY ATTEMPT SHOULD BE MADE TO DELAY THE TIME WHERE THE ACCELERATION CUE REVERSES SIGN (TC) UNTIL AFTER THE NORMAL PILOT REACTION TIME HAS ELAPSED.

3. SOME METHOD OF PROGRAMMING THE INPUTS TO THE MOTION BASE IS REQUIRED WHICH WILL ENSURE THAT LITTLE OR NO ACCELERATION CUES ARE PRODUCED FOR AIRCRAFT ACCELERATIONS OTHER THAN

THOSE DUE TO ENGINE FAILURES.

FOR THE PARTICULAR CASE OF THE BOEING 737, A VERY GOOD SIMULATION CAN BE ACHIEVED USING A WASHOUT FILTER OF $1/(S+.5)$ SQUARED WITH A MAXIMUM AMPLITUDE OF 4 FEET AND A LIMITING VELOCITY OF AT LEAST 2 FEET PER SECOND.

IF THE MAXIMUM AMPLITUDE AVAILABLE IS SMALLER THAN THIS, SOME ADDITIONAL TECHNIQUES MAY NEED TO BE EMPLOYED TO ENSURE THAT THE MOTION CUE TO THE PILOT IS NOT CONFUSING. THE TESTS HAVE SHOWN LITTLE TO CHOOSE BETWEEN 1 FOOT AND 1/3 FOOT MAXIMUM MOTION LIMITS. THEY BOTH SUFFER FROM THE SAME SPURIOUS AND CONFUSING ACCELERATIONS, AND THE CURE FOR THIS MUST BE LOOKED FOR IN SOME OTHER TECHNIQUE. SOME POSSIBLE METHODS ARE DISCUSSED IN 4.0.

SPRING, 1976.

ADVANCED FLIGHT SIMULATION IN AIR COMBAT TRAINING NORTHROP CORP.
FOR AIAA VISUAL AND MOTION SIMULATION CONFERENCE, DAYTON, OHIO,
APRIL 26-28, 1976.

* ABSTRACT *

THE BASIC CHALLENGE WAS TO CREATE A SIMULATION TO SUPPORT TWO AIR COMBAT PILOT TRAINING EXPERIMENTS FOR THE U. S. NAVY, USING THE RESOURCES OF AN ADVANCED AIRCRAFT DESIGN SIMULATION LABORATORY. THE FIRST EXPERIMENT DEALT WITH TRANSFER OF LEARNING FROM THE SIMULATOR PRE-TRAINING TO AIRBORNE TRAINING FOR SIX INITIAL AIR COMBAT TRAINING SORTIES IN F-4JS. THE SECOND EXPLORED THE FEASIBILITY OF AUTOMATED PERFORMANCE MEASURES FOR AIR COMBAT TRAINING. THE OBVIOUS PROBLEM WAS PROVIDING ONE-ON-ONE AIR COMBAT TRAINING CAPABILITY WITH A SINGLE SIMULATOR. THE SOLUTION WAS TO DEVELOP SUITABLE REAL TIME DISPLAYS AND CONTROLS FOR THE INSTRUCTORS CONSOLE. A KEY ELEMENT OF THE SUCCESS OF THE SIMULATION WAS THE VARIETY OF TARGET AIRCRAFT CONTROL MODES. LIMITLESS EVALUATION CAPABILITY WAS PROVIDED BY BOTH INSTANT AND ARCHIVAL REPLAY. IN OPERATION, A SINGLE AIRCRAFT SIMULATOR WITH APPROPRIATE INSTRUCTOR'S CONSOLE MAY BE USED IN LIEU OF MULTIPLE AIRCRAFT SIMULATORS FOR INITIAL PRE-TRAINING OF AIR COMBAT. THE SIMULATION, WHEN USED BY AN OPERATIONAL NAVY TRAINING SQUADRON, HAS PROVEN AN EFFECTIVE AID IN THE INITIAL TRAINING OF AIR COMBAT TASKS. THE USE OF AN ADVANCED AIRCRAFT DESIGN FLIGHT SIMULATION FACILITY HAS BEEN EFFECTIVE IN PERFORMING LIMITED FLIGHT TRAINING RESEARCH.

STANKE, PETER. STUDY OF CAPABILITIES, NECESSARY CHARACTERISTICS AND EFFECTIVENESS OF PILOT GROUND TRAINERS, VOL. II - ADDENDUM, SUMMARY OF FLIGHT INSTRUCTOR'S VIEWS. LEAR SIEGLER, INC. FOR NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER, ATLANTIC CITY, NEW JERSEY, REPORT FAA-RO-72-127, II. AD-755 682, JAN 1973

* ABSTRACT *

AN EXPERIMENT WAS CONDUCTED TO TEST THE CAPABILITIES, NECESSARY CHARACTERISTICS, AND EFFECTIVENESS OF PILOT GROUND TRAINERS IN DEVELOPING PRIMARY AERONAUTICAL SKILLS, THOSE MANEUVERS AND PROCEDURES DEFINED IN FEDERAL AIR REGULATIONS 61.37, 61.87, 61.117 AND APPROPRIATE FLIGHT TEST GUIDES, LIMITED TO AIRCRAFT, SINGLE-ENGINE, LAND. DURING THE FIRST PHASE OF THE EXPERIMENT, 30 SUBJECTS WERE TRAINED TO PROFICIENCY UNDER PART 61.87, FIFTEEN IN AIRCRAFT ONLY, AND FIFTEEN IN COMBINED GROUND TRAINER AND AIRCRAFT. DURING THE NEXT PHASE, 20 OF THE ORIGINAL 30 WERE TRAINED TO PROFICIENCY UNDER 61.37 AND 61.117, 10 IN EACH GROUP. A THIRD PHASE OF THE EXPERIMENT TESTED ADDITIONAL SUBJECTS IN VARIOUS PROCEDURES WITH VARYING LEVELS OF SIMULATOR CAPABILITY. THE RESULTS OF THE EXPERIMENT SHOW WHICH MANEUVERS AND PROCEDURES MAY BE TAUGHT EFFECTIVELY AND EFFICIENTLY IN A GROUND TRAINER. THIS ADDENDUM REVIEWS FLIGHT INSTRUCTORS' IDEAS ON THE APPLICABILITY OF GROUND TRAINERS IN A PRIMARY CURRICULUM, BASED UPON THEIR EXPERIENCE IN THIS PROJECT. VOLUME I CONTAINS THE MAIN TEXT.

STANEK, P. STUDY OF CAPABILITIES, NECESSARY CHARACTERISTICS AND EFFECTIVENESS OF PILOT GROUND TRAINERS, VOL. I - MAIN TEXT. SYSTEMS TECHNOLOGY CENTER, LEAR SIEGLER, INC., PREPARED FOR THE FEDERAL AVIATION ADMINISTRATION, WASH., D.C., REPORT FAA-RC-72-127, I, JANUARY 1973, AD-755 681.

* ABSTRACT *

AN EXPERIMENT WAS CONDUCTED TO TEST THE CAPABILITIES, NECESSARY CHARACTERISTICS, AND EFFECTIVENESS OF PILOT GROUND TRAINERS IN DEVELOPING PRIMARY AERONAUTICAL SKILLS, THOSE MANEUVERS AND PROCEDURES DEFINED IN FEDERAL AIR REGULATIONS 61.37, 61.87, 61.117 AND APPROPRIATE FLIGHT TEST GUIDES, LIMITED TO AIRCRAFT, SINGLE-ENGINE, LAND. DURING THE FIRST PHASE OF THE EXPERIMENT, 30 SUBJECTS WERE TRAINED TO PROFICIENCY UNDER PART 61.87, FIFTEEN IN AIRCRAFT ONLY AND FIFTEEN IN COMBINED GROUND TRAINER AND AIRCRAFT. DURING THE NEXT PHASE, 20 OF THE ORIGINAL 30 WERE TRAINED TO PROFICIENCY UNDER 61.37 AND 61.117, 10 IN EACH GROUP. A THIRD PHASE OF THE EXPERIMENT TESTED ADDITIONAL SUBJECTS IN VARIOUS PROCEDURES WITH VARYING LEVELS OF SIMULATOR CAPABILITY. THE RESULTS OF THE EXPERIMENT SHOW WHICH MANEUVERS AND PROCEDURES MAY BE TAUGHT EFFECTIVELY AND EFFICIENTLY IN A GROUND TRAINER. VOLUME II CONTAINS THE ADDENDUM, SUMMARY OF FLIGHT INSTRUCTORS' VIEWS.

STAPLEFORD, R.L. MULTIMODALITY PILOT MODEL FOR VISUAL AND MOTION CUES. FEBRUARY, 1968. IN FOURTH ANNUAL NASA-UNIVERSITY CONFERENCE ON MANUAL CONTROL, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN, MARCH 21-23, 1968. NASA SP-192.

* ABSTRACT *

A PRELIMINARY MODEL FOR PILOT CONTROL BEHAVIOR WHEN UTILIZING BOTH VISUAL AND MOTION CUES IS PRESENTED. THE MODEL IS BASED ON A DETAILED REVIEW OF ALL KNOWN DATA, INCLUDING SOME UNPUBLISHED DATA FROM RECENT EXPERIMENTS CONDUCTED BY NASA-ARC AND STI. MODELS FOR THE THREE FEEDBACK PATHS (VISUAL, ANGULAR MOTION, AND LINEAR MOTION) AND INTEGRATION OF THE VARIOUS FEEDBACKS ARE DESCRIBED.

STAFFORD, R.L., PETERS, R.A. AND ALEX, F.R. 'EXPERIMENTS AND A MODEL FOR PILOT DYNAMICS WITH VISUAL AND MOTION INPUTS'. NASA CR-1325, MAY 1969.

* ABSTRACT *

THIS REPORT DESCRIBES THE RESULTS OF A SIMULATOR PROGRAM TO INVESTIGATE THE EFFECTS OF MOTION CUES ON A MANUAL CONTROL TRACKING TASK. THE EXPERIMENTAL VARIABLES WERE CONTROLLED. ELEMENT DYNAMICS, LINEAR MOTION CHARACTERISTICS, AND ANGULAR MOTION CHARACTERISTICS. THE DATA OBTAINED INCLUDE: PILOT DESCRIBING FUNCTIONS, BOTH OVERALL (COMBINED VISUAL AND MOTION FEEDBACKS) AND SEPARATE (INDEPENDENT VISUAL AND MOTION PATHWAYS) REMNANT CHARACTERISTICS, AND TRACKING PERFORMANCE. THESE DATA ARE ALSO COMPARED WITH PREVIOUS EXPERIMENTAL RESULTS.

FROM THE PREVIOUS AND PRESENT DATA, A MULTIMODALITY PILOT MODEL FOR BOTH VISUAL AND MOTION FEEDBACKS IS DERIVED. THE DYNAMICS OF THE TWO (ANGULAR AND LINEAR) MOTION FEEDBACK PATHS AND THE INTEGRATION OF VISUAL AND MOTION FEEDBACKS ARE DISCUSSED. THE OVERALL EFFECTS OF MOTION ON THE CROSSOVER MODEL ARE FOUND TO BE THE LOWER PILOT EFFECTIVE TIME DELAYS AND HIGHER CROSSOVER FREQUENCIES. THE CHANGES ARE ROUGHLY 0.15 SEC. AND 1 RAD/SEC. THESE EFFECTS ARE PRIMARILY DUE TO AN ANGULAR RATE FEEDBACK VIA THE SEMICIRCULAR CANALS. THE LEAD PROVIDED BY THIS VESTIBULAR PATH ALLOWS THE PILOT TO REDUCE HIS LEAD IN THE VISUAL PATH AND INCREASE HIS LOW FREQUENCY GAIN. THE RELATIVE MAGNITUDES OF THE VISUAL AND VESTIBULAR FEEDBACKS DEPEND ON THE CONTROLLED ELEMENT DYNAMICS (WHETHER OR NOT PILOT LOW FREQUENCY LEAD EQUALIZATION IS REQUIRED).

THE IMPLICATIONS OF THE EXPERIMENTAL DATA AND THE MULTIMODALITY PILOT MODEL ON THE DESIGN REQUIREMENTS FOR MOVING-BASE SIMULATORS ARE ALSO REVIEWED. WHILE THE EFFECTS OF MOTION CUES ON MANUAL TRACKING, FAILURE DETECTION, AND REALISM MUST BE CONSIDERED, THE ONLY DEFINITIVE REQUIREMENTS ARE THOSE RELATING TO TRACKING. TRANSLATIONAL MOTION CUES APPEAR TO BE GENERALLY LESS IMPORTANT THAN ROTATIONAL ONES, ALTHOUGH LINEAR MOTIONS CAN BE SIGNIFICANT IN SPECIAL SITUATIONS. A CONSERVATIVE ESTIMATE FOR THE REQUIREMENTS ON ANGULAR CUES SEEMS TO BE GOOD FIDELITY OVER THE FREQUENCY RANGE OF 0.5-10 RAD/SEC. A PROCEDURE FOR ESTABLISHING TRACKING REQUIREMENTS FOR A SPECIFIC PROBLEM IS OUTLINED.

STAFLES, K.J.
MOTION, VISUAL AND AURAL CUES IN PILOTED FLIGHT SIMULATION.
'AGARD CONFERENCE PROCEEDINGS ON SIMULATION' AGARD-CP-79-70
(ALSO: RAE TECHNICAL MEMORANDUM AERO 1196, JAN. 1970.)

* ABSTRACT *

AN ANALYSIS IS MADE OF THE PART PLAYED BY THE VARIOUS CUES IN SIMULATION. THE AIM IS TO HIGHLIGHT THE PROBLEMS RATHER THAN TO SUMMARIZE THE STATE-OF-THE-ART. EACH CUE IS CONSIDERED IN TURN WITH PARTICULAR EMPHASIS ON THE INTERACTION WITH HUMAN PHYSIOLOGICAL SENSORS. THE DEFICIENCIES IN THE CUES COMPARED WITH FLYING AN ACTUAL AIRCRAFT ARE STATED, AND SOME ASSESSMENT OF THEIR RELATIVE IMPORTANCE IS ATTEMPTED. THE SUBSTITUTION OF ONE CUE BY ANOTHER IS MENTIONED AND THE EFFECTS OF INTERACTION BETWEEN CUES IS DISCUSSED.

STARK, E.A. 747 BROCHURE, COCKPIT MOTION. 'GENERAL PRECISION, INC., LINK GROUP - SYSTEMS DIVISION', PAPER DATED AUGUST 22, 1966.

* ABSTRACT *

COCKPIT MOTION IS A MAJOR SOURCE OF INFORMATION FOR MANUAL FLIGHT CONTROL. WHILE TODAY'S PILOTS DO NOT FLY ENTIRELY BY 'THE SEAT OF THE PANTS', THEY DO RESPOND TO AND USE MANY OF THE SUBTLE CUES PRODUCED BY AIRCRAFT MOTION, TO MAINTAIN SMOOTH AND EFFECTIVE CONTROL. AS A RESULT, FAITHFUL SIMULATION OF FLIGHT CONDITIONS REQUIRES ACCURATE REPRESENTATION OF CUES TO COCKPIT MOTION, TO ASSURE MAXIMUM SIMULATOR UTILITY IN PREPARING PILOTS FOR OPERATIONAL FLIGHT.

THE DESIGN OF THE COCKPIT MOTION SYSTEM FOR THE BOEING 747 SIMULATOR IS BASED ON EXTENSIVE RESEARCH INTO THE PERCEPTION AND UTILIZATION OF MOTION CUES BY PILOTS. THREE BASIC PRINCIPLES ABOUT MAN'S PERCEPTION OF MOTION HAVE BEEN TAKEN INTO ACCOUNT IN THE SYSTEM'S DESIGN:

1. HUMANS DO NOT SENSE MOTION AS SUCH, BUT ONLY CHANGES IN THE RATE AND DIRECTION OF MOTION.
2. CONSTANT BODY POSITIONS AROUND THE LONGITUDINAL AND LATERAL AXES (ROLL AND PITCH) ARE SENSED QUITE ACCURATELY AS DEVIATIONS FROM THE UPRIGHT, BECAUSE THEY PRODUCE CHANGES IN THE DIRECTION OF ACCELERATION DUE TO GRAVITY.
3. MANY ACCELERATIONS WITHIN THE RANGE OF AIRCRAFT CAPABILITY ARE TOO SMALL TO BE SENSED. A CONSTANT AND SIGNIFICANT RATE OF TURN FOR EXAMPLE, CAN RESULT FROM AN IMPERCEPTIBLE ACCELERATION INDUCED BY AN OUT-OF-TRIM CONDITION AND INATTENTION TO THE

INSTRUMENTS.

THE 747 SIMULATOR MOTION SYSTEM PROVIDES APPROPRIATE CUES IN ALL SIX DEGREES OF FREEDOM. IT PROVIDES THE PITCH AND VERTICAL TRAVEL CUES ASSOCIATED WITH TAKEOFF ROTATION, THE VARIOUS CLIMBING AND LET-DOWN CONFIGURATIONS, AND TURBULENCE. IT PROVIDES THE BANK ANGLE CUES PRODUCED BY UNCOORDINATED TURNS AND BY ROUGH AIR, AND IT REPRESENTS THE LATERAL ACCELERATIONS ASSOCIATED WITH TURN ENTRY, AND RECOVERY. IT ALSO PROVIDES THE LONGITUDINAL AND LATERAL ACCELERATIONS WHICH MAKE UP THE MOST IMMEDIATE INFORMATION RECEIVED BY THE PILOT ABOUT RUNWAY CONDITIONS IN TAKEOFF, LANDING AND TAXIING, AND ABOUT THRUST, BRAKE, FLAP, AND STEERING FAILURES. THE MOTION SYSTEM PROVIDES THESE CUES, WITHIN A LIMITED MOTION ENVELOPE, BY PRODUCING ONSETS AND ACCELERATIONS OVER PERIODS OF TIME COMMENSURATE WITH THEIR ACTUAL DURATIONS IN THE AIRCRAFT, AND BY FADING THE COCKPIT TRAVEL REQUIRED TO PRODUCE THEM, AT RATES BELOW THE PILOT'S SENSORY THRESHOLDS.

THREE OF THESE MOTION CUES MUST BE SUSTAINED OVER EXTENDED PERIODS, TO TRULY REPRESENT AIRCRAFT BEHAVIOR. PITCH AND ROLL ARE SUSTAINED BY HOLDING THE COCKPIT STATIC, AT THE APPROPRIATE ANGLE. THE VERTICAL ACCELERATION ACCOMPANYING EXTENDED TURNS IS NOT SUSTAINED AS SUCH THROUGHOUT THE TURN, HOWEVER, BUT IS SIMULATED THROUGH A UNIQUE MOTION SEAT, IN WHICH VARIATIONS IN SEAT FOLT PRESSURE SIMULATE THE POSITIVE AND NEGATIVE ACCELERATIONS WHICH RESULT FROM CHANGES IN TURN RATE OR IN PITCH CONTROL IN TURN ENTRY, TURNING AND TURN RECOVERY. THE MOTION SEAT, THUS PERMITS THE PILOT TO MAINTAIN BANK ANGLE AND ALTITUDE IN TURNS WITHOUT SPENDING A DISPROPORTIONATE AMOUNT OF TIME MONITORING THE FLIGHT INSTRUMENTS.

THE COCKPIT MOTION SYSTEM IS UNIQUE IN THE COMPLETENESS WITH WHICH IT REPRESENTS THOSE CHARACTERISTICS OF THE AIRCRAFT REQUIRED FOR COMPLETE PILOT TRAINING.

STARK, E. A.
MOTION PERCEPTION AND TERRAIN VISUAL CUES IN AIR COMBAT SIMULATION.

(SINGER CO., SIMULATION PRODUCTS DIVISION, BINGHAMTON, N. Y.)
IN VISUAL AND MOTION SIMULATION CONFERENCE, DAYTON OHIO

APRIL 26-28, 1976.

PROCEEDINGS (A76-29478 13-53) NEW YORK,

AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS INC. 1976.

D 39-49.

* ABSTRACT *

EVALUATIONS WERE MADE OF A TERRAIN VISUAL SIMULATION SYSTEM AND A MULTICOMPARTMENTED G-SENSITIVE SEAT IN AN AIR COMBAT SIMULATOR. THESE SYSTEMS PROVIDED SOME OF THE CUES ASSOCIATED WITH HIGH PERFORMANCE AIR COMBAT MANEUVERS. A RELATIVELY SIMPLE CHECKERBOARD DISPLAY PROVIDED VISUAL CUES WHICH SUPPORTED

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REALISTIC PRACTICE IN THE CONTROL OF ALTITUDE, ALTITUDE RATE, HEADING, GROUND VELOCITY AND RATE OF CLOSURE WITH THE SURFACE OF THE SIMULATED TERRAIN. THE G-SEAT SUPPLEMENTED CUES PROVIDED BY THE COCKPIT MOTION SYSTEM, PERMITTING FINE CONTROL OF SUSTAINED ACCELERATIONS AND REALISTIC RESPONSE TO MINUTE BUT CRITICAL FLIGHT PATH AND ATTITUDE DEVIATIONS. EACH SYSTEM REPRESENTED ONLY A PART OF THE INFORMATION AVAILABLE IN ACTUAL FLIGHT, IN ITS AREA OF SIMULATION AND YET EACH PROVIDED ENOUGH INFORMATION TO SUPPORT COMPLEX PILOT PERFORMANCE NEARLY EQUIVALENT TO THAT EXPECTED IN THE AIRCRAFT.

STARR, E.A., FACCONTI, V. AND MORTIMER, C. STUDY TO DETERMINE THE REQUIREMENTS FOR AN EXPERIMENTAL TRAINING SIMULATION SYSTEM. NAVTRADEVEN 69-C-0207-1, 'NAVAL TRAINING DEVICE CENTER' PROJECT NO. 8249-A, 1971.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DESIGN A SIMULATION SYSTEM CAPABLE OF SUPPORTING HUMAN FACTORS EXPERIMENTS IN THE DEVELOPMENT OF TRAINING DEVICE DESIGNS. THE FIRST PHASE OF THE STUDY CONSISTED OF A REVIEW OF TASKS PERFORMED BY THE OPERATORS OF FOUR GENERAL TYPES OF MILITARY SYSTEMS, AN ANALYSIS OF PROBLEMS EXPERIENCED IN THE DEVELOPMENT OF DEVICES FOR TRAINING THESE TASKS AND THE IDENTIFICATION OF DESIGN AREAS IN WHICH EXPERIMENTATION IS REQUIRED. AS PART OF THIS EFFORT, INFORMATION ON MOTION SIMULATION WAS PRESENTED. PARA 2.1 OF SECTION VII DESCRIBED THE MOTION SYSTEM PROPOSED FOR THE EXPERIMENTAL TRAINING SIMULATION SYSTEM (ETSS). THE RELATIVE MERITS OF SYNERGISTIC AND CASCADED MOTION SYSTEMS ARE BRIEFLY DISCUSSED IN APPENDIX I. SEVERAL TABLES LIST MOTION SYSTEM CHARACTERISTICS:

- TABLE 8 - SUMMARIZES MAXIMUM MOTION PARAMETERS.
- 9 - TYPICAL CHARACTERISTICS OF ETSS MOTION SYSTEM.
- 18 - SUMMARY OF AIRBORNE VEHICLE MOTION SYSTEM CHARACTERISTICS.
- 20 - ROLLING PERIODS AND ANGLES ON TYPICAL VOYAGES (MARINE VEHICLES).
- 21 - CHARACTERISTICS OF MOTION FOR U. S. NAVAL VESSELS.

STARR, E.A. AND WILSON, J.M. 'VISUAL AND MOTION SIMULATION IN ENERGY MANEUVERING'. SINGER SIMULATION PRODUCTS DIVISION, BINGHAMTON, NEW YORK, PAPER NO. 73-934 AT AIAA VISUAL AND MOTION SIMULATION CONFERENCE, PALO ALTO CALIFORNIA, SEPT 10-12, 1973.

* ABSTRACT *

PILOT EVALUATIONS WERE MADE OF AN F-4 FLIGHT SIMULATOR WITH A SIX DEGREE OF FREEDOM MOTION SYSTEM, A TERRAIN VISUAL SYSTEM,

AND A G-SUIT. THE EVALUATION MANEUVERS REQUIRED CONTROL CLOSE TO THE EDGES OF THE AIRCRAFTS AERODYNAMIC AND STRUCTURAL ENVELOPES. PILOT COMMENTS INDICATED THAT VERY HIGH FIDELITY DATA ARE REQUIRED IN SIMULATING MARGINAL AIRCRAFT PERFORMANCE. VISUAL CUES AND MOTION IN ALL SIX DEGREES OF FREEDOM ARE REQUIRED TO PERMIT CONTROL WITHOUT EXCESSIVE INSTRUMENT REFERENCE. CUES TO G-FORCES, SUSTAINED ACCELERATION, BUFFET AND VIBRATION ARE REQUIRED TO PERMIT EFFICIENT CONTROL WITHIN STRUCTURAL LIMITS.

STARK, E.A. AND WILSON, J.M., JR. SIMULATION OF VISUAL AND MOTION CUES IN AIR COMBAT MANEUVERING. IN 'NAVAL TRAINING EQUIPMENT CENTER REPORT' IH-226, PROCEEDINGS OF THE SIXTH NTEC/INDUSTRY CONFERENCE, NOV. 13-15, 1973.

* ABSTRACT *

THE PURPOSE OF THIS PAPER IS TO REPORT THE PROCEDURES EMPLOYED IN THE DEVELOPMENT, EVALUATION, INTEGRATION, AND MODIFICATION OF THE COCKPIT MOTION, TERRAIN VISUAL AND G-SUIT SYSTEMS, AND THE MAJOR RESULTS OF THE EVALUATIONS OF THE SIMULATOR FOR AIR-TO-AIR COMBAT (SAAC) CONDUCTED IN 1972. THE PROBLEM WAS TO DEVELOP SYSTEMS CAPABLE OF PROVIDING RELEVANT CUES FOR AIR-TO-AIR COMBAT, TO EVALUATE THESE SYSTEMS AND TO PROGRESSIVELY INTEGRATE THEM INTO THE SIMULATOR.

STEIN, K.C. DIGITAL COMPUTERS TO AID FLIGHT TRAINING. AVIATION WEEK AND SPACE TECHNOLOGY, MARCH 4, 1968, PP. 61-67.

* ABSTRACT *

ABSTRACT (MOTION SECTION)

IMPROVED MOTION SYSTEMS CAN NOW PERMIT A STUDENT TO EXPERIENCE A SIMULATED JOLT TO ALERT HIM TO DANGER CONDITIONS SUCH AS A SUDDEN ASYMMETRIC THRUST OR TO MORE NORMAL SENSORY SIGNALS SUCH AS THE SLIGHT BUFFETING ACCOMPANYING APPLICATION OF SPOILERS, OR A THUMP ACCOMPANYING LOWERING OF THE GEAR.

UNTIL THE DEVELOPMENT OF NEW SIX-DEGREE-OF-FREEDOM MOTION SYSTEM BEGAN, THERE WAS NOT MUCH RESEARCH AND NO COMPREHENSIVE BODY OF STUDY OF WHAT IS NEEDED TO PRODUCE POSITIVE MOTION CUES, ACCORDING TO LINK OFFICIALS.

INTERVIEWS WITH SIMULATOR USERS, PILOTS AND INSTRUCTORS AND EVALUATION OF VARIOUS DEGREES OF TRAINING PRODUCED THE CONCLUSION THAT PITCH IS PROBABLY THE MOST IMPORTANT CUE, WITH OTHERS OF VARYING VALUE.

THE ARTICLE ALSO DISCUSSES THE IMPORTANCE OF SOME OF THE OTHER

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CLUES AS WELL AS THE AMOUNT OF MOTION REQUIRED TO PRODUCE VARIOUS MOVEMENTS. FINALLY, THEY DESCRIBE THE CAPABILITIES OF THE 747 SIMULATOR.

STEIN, K.C. USAF PLACES NEW STRESS ON SIMULATORS. AVIATION WEEK AND SPACE TECHNOLOGY, JUNE 26, 1972 (PUIG)

* ABSTRACT *

NO ABSTRACT GIVEN

STEWART, J.D. HUMAN PERCEPTION OF ANGULAR ACCELERATION AND IMPLICATIONS IN MOTION SIMULATION. AIAA PAPER 70-350, 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE', CAPE CANAVERAL, FL., MARCH 16 - 18, 1970.
(ALSO IN J. OF AIRCRAFT, 1971, 8, 248-253)

* ABSTRACT *

DATA ON HUMAN SUBJECTIVE RESPONSE TO ANGULAR ACCELERATION COLLECTED ON THE AMES MAN-CARRYING ROTATION DEVICE ARE PRESENTED AND THE IMPLICATIONS OF THESE DATA TO MOTION SIMULATION ARE DISCUSSED. THRESHOLD DATA HAVE BEEN OBTAINED FOR SEVERAL STIMULUS DURATIONS, THREE AXES OF ROTATION, AND TWO RESPONSE INDICATORS. THESE THRESHOLDS INDICATE THAT THE AVERAGE PILOT CAN BE VERY SENSITIVE TO ANGULAR ACCELERATION. FIRST-ORDER APPROXIMATIONS TO THE HUMAN DYNAMIC RESPONSE TO ANGULAR ACCELERATIONS ARE DERIVED FROM FOUR EXPERIMENTS AND RESULTING TIME CONSTANTS VARY FROM 4 TO 10 SEC DEPENDING ON THE OBSERVER'S TASK. IT IS DEMONSTRATED THAT A SIMPLE STATIC WASHOUT CONCEPT REQUIRING CONTINUOUS ROTATIONS AT SUBTHRESHOLD LEVELS PROVIDES ESSENTIALLY USELESS REDUCTIONS IN SIMULATOR TRAVEL. THE VARIATION IN THE APPARENT DYNAMICS DERIVED FROM THE PSYCHOPHYSICAL DATA SUGGEST THAT SIMULATOR WASHOUT CHARACTERISTICS MAY HAVE TO BE TAILORED TO EACH SIMULATED FLIGHT CONFIGURATION OR PILOTING TASK. (AUTHOR)

STEWART, J.D. AND CLARK, B. CORIOLIS EFFECTS DURING PITCH AND ROLL MANEUVERS IN A PILOTED FLIGHT SIMULATOR. 'AEROSPACE MEDICINE', FEB. 1965.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO DETERMINE THE EFFECTS OF SUPRATHRESHOLD VALUES OF CORIOLIS ACCELERATION ON THE PILOT OF A FLIGHT SIMULATOR WITH PARTICULAR REFERENCE TO HIS PERCEPTION OF ILLUSORY MOTION AND HIS POSITION IN SPACE. THE PARTICULAR CORIOLIS STIMULI SELECTED WERE THOSE THAT WOULD BE ANTICIPATED

IN THE USE OF THE AMES FIVE-DEGREES-OF-FREEDOM SIMULATOR IN STUDIES OF AIRCRAFT AND SPACECRAFT. THREE MODELS OF SIMULATOR MOTION WERE USED: ROTATION OF THE COCKPIT AROUND THE Z AXIS AT 30 FEET FROM THE CENTER OF ROTATION, AND PITCH AND ROLL OF THE COCKPIT. THE DATA CONSISTED OF SUBJECTIVE REPORTS OF APPARENT MOTION AND ESTIMATES OF BODY POSITION. SEVEN EXPERIENCED OBSERVERS WHO SHOWED NORMAL POST-ACCELERATION AND POST-DECELERATION AFTER EFFECTS OF ROTATION ON THE SIMULATOR WERE USED. TWO WERE RESEARCH PILOTS, AND THE OTHERS WERE THE AUTHORS AND THREE MEMBERS OF THE AMES STAFF.

THE FREQUENCY OF REPORTS OF CORIOLIS EFFECTS INCREASED AS A FUNCTION OF SIMULATOR VELOCITY FROM 2 TO 12 RPM FOR BOTH PITCH AND ROLL MANEUVERS. THE FREQUENCY OF THE CORIOLIS EFFECTS WAS NEARLY 100 PER CENT AT 7 RPM AND ABOVE. THE DURATION OF THE CORIOLIS EFFECTS ALSO INCREASED AS A FUNCTION OF THE SIMULATOR VELOCITY, THE DURATION OF THE EFFECTS FOR PITCH AND ROLL BEING VERY SIMILAR. THE MEAN DURATION OF THE REPORTED ROTATION WAS APPROXIMATELY 9 SECONDS AT 2 RPM AND 15 SECONDS AT 12 RPM, FOR THE PITCH AND ROLL MANEUVERS USED.

THE OBSERVERS' ESTIMATE OF BODY POSITION TENDED TO BE VERY CLOSE TO THE DEVIATION OF HIS BODY POSITION FROM THE DIRECTION OF THE RESULTANT FORCE ACTING ON HIM UNDER THE VARIOUS EXPERIMENTAL CONDITIONS. THE OBSERVERS DID, HOWEVER, TEND TO UNDERESTIMATE THE VARIATION OF THEIR BODY POSITION AT THE LOWER VELOCITIES IN ACCORDANCE WITH SIMILAR STATIC ESTIMATES, BUT THEY TENDED TO BE CLOSE TO THE CORRESPONDING ANGLE AT 12 RPM.

STITT, C. E.
APPLICATION OF FLIGHT SIMULATION TECHNOLOGY.
LANGLEY RESEARCH CENTER, LANGLEY STATION, VA.
W77-70117, 505-C9-41. 1977.

* ABSTRACT *

THE OBJECTIVE IS TO APPLY SIMULATION TECHNOLOGY TO EXISTING FLIGHT SIMULATORS TO SUPPORT LANGLEY RESEARCH PROGRAMS. THIS TYPE WILL COVER BOTH IN-HOUSE AND CONTRACTUAL STUDIES WHICH ADDRESS CURRENT CONSTRAINTS IN LANGLEY SIMULATOR EQUIPMENT, IN THE FORMULATION AND VALIDATION OF SIMULATION MATH MODELS, AND IN THE LINKAGE OF THE HARDWARE SOFTWARE SYSTEMS TO PROVIDE, IN THE CLOSED-LOOP PILOT/SIMULATOR ENVIRONMENT, EFFECTIVE SIMULATIONS. PRINCIPAL TASKS FOR FY-77 INCLUDE STUDIES OF MODEL REQUIREMENTS FOR RSRA SIMULATION, EVALUATION OF KINESTHETIC CUES FOR DMS, DEVELOPMENT OF IMPROVED REAL-TIME SIMULATION COMPUTING TECHNIQUES FOR THE REAL-TIME SIMULATION SYSTEM AND VALIDATION OF THE MAN-MACHINE SYSTEMS MODEL FOR ANALYSIS OF FLIGHT SIMULATOR ENGINEERING REQUIREMENTS. RESULTS OF THE EFFORT WILL BE DOCUMENTED IN NASA TECHNICAL NOTES AND CONTRACTOR REPORTS, AND WILL BE APPLIED TO SIMULATIONS OF INTEREST TO LANGLEY RESEARCH CENTER.

STODDART, S.A. A FLIGHT DYNAMICS EVALUATION OF A SINGER-LINK GAT-2 AS A QUASI-SIMULATOR WITH CONTROL MODIFICATIONS. MASTER'S THESIS, AVIATION RESEARCH LAB., INSTITUTE OF AVIATION, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN, REPORT ARL-71-13/AFOSR-71-4, AD-731 135, JUN 1971.

* ABSTRACT *

THE FLIGHT DYNAMICS OF A SINGER-LINK GENERAL AVIATION TRAINER-2 (GAT-2) ARE ANALYZED THEORETICALLY AND EXPERIMENTALLY TO DETERMINE THE FIDELITY OF THE SIMULATION OF A LIGHT TWIN-ENGINE AIRPLANE. THE SIMULATION IS SHOWN TO BE REASONABLE FOR EXPERIMENTAL PURPOSES. FOUR CONTROL MODIFICATIONS, SIDESLIP COMPENSATION, LIFT COMPENSATION, POSITION-POSITION ROLL CORRESPONDENCE, AND FOLLOW-UP TRIM, ARE PRESENTED AND DOCUMENTED. (AUTHOR)

STONE, R.W. RIDE QUALITY - AN EXPLORATORY STUDY AND CRITERIA DEVELOPMENT. NASA TM-X-71922, 1974.

* ABSTRACT *

THE LANGLEY SIX DEGREE-OF-FREEDOM VISUAL MOTION SIMULATOR WAS USED TO MEASURE SUBJECTIVE RESPONSE RATINGS OF RIDE QUALITY OF FLIGHT SEGMENTS OF FLIGHT WHICH, IT WAS JUDGED, WOULD PRODUCE A WIDE AND REPRESENTATIVE VARIATION IN COMFORT ESTIMATES. THE RESULTS INDICATE THAT THE USE OF SIMULATORS FOR THIS PURPOSE SEEMS PROMISING. THE AUTHOR SUGGESTS CRITERIA FOR RIDE QUALITY RATINGS, BASED ON PSYCHOPHYSICAL PRECEPTS.

STONE, R.W. SIMULATOR STUDIES AND PSYCHOPHYSICAL RIDE-COMFORT MODELS. NASA TM-X-3295, 1975.

* ABSTRACT *

A PSYCHOPHYSICAL MODEL TO PREDICT RIDE-COMFORT WAS DEVELOPED USING FLIGHT AND SIMULATOR DATA. THE MODEL PRESUMES THAT THE COMFORT RESPONSE IS PROPORTIONAL TO THE LOGARITHM OF THE STIMULUS ABOVE SOME THRESHOLD VALUE. TO VERIFY THIS CONCEPT OF COMFORT MODELLING, THE AUTHOR HAD TO OBTAIN RIDE-COMFORT DATA FOR SINGLE DEGREE-OF-FREEDOM RANDOM MOTIONS AND FOR COMBINATIONS OF DEGREES-OF-FREEDOM RANDOM MOTIONS. ACCORDINGLY, A SIMULATOR PROGRAM WAS UNDERTAKEN TO MEASURE SUBJECTIVE COMFORT RESPONSE RATINGS USING ONE DEGREE, TWO DEGREES, THREE DEGREES AND SIX DEGREES-OF-FREEDOM OF MOTION. AN ANALYSIS OF THE SINGLE DEGREE-OF-FREEDOM OF MOTION. AN ANALYSIS OF THE SINGLE DEGREE-OF-FREEDOM DATA IS PRESENTED. PRELIMINARY MODELS OF THE RIDE-COMFORT RESPONSE FOR SINGLE DEGREE-OF-FREEDOM RANDOM MOTIONS AND FOR

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CERTAIN COMBINATIONS OF TWO DEGREES-OF-FREEDOM RANDOM MOTIONS
HAVE BEEN DEVELOPED.

STERN, G.C. COLLINS RADIO, DALLAS, TEXAS. POSITIONING DEVICE
CONTINUOUS IN AZIMUTH AND ELEVATION USING MULTIPLE LINEAR DRIVES
PATENT NO. 3,215,391
DATE FILED - JUNE 29, 1964 DATE GRANTED - NOV. 2, 1965

NO ABSTRACT

STREIFF, H.A. 'SURVEY OF HELICOPTER AND V/STOL AIRCRAFT SIMULA-
TOR TRAINING'. NAVTRADEVEN 1753-1. U.S. NAVAL TRAINING DEVICE
CENTER, PORT WASHINGTON, NEW YORK 1966.

* ABSTRACT *

THE RESULTS OF A STUDY TO DETERMINE THE DYNAMIC RESPONSE
CRITERIA FOR HELICOPTER SIMULATOR TRAINERS ARE PRESENTED. THE
FUNDAMENTALS OF HELICOPTER DYNAMICS, CONTROL AND SIMULATION ARE
DESCRIBED WITHIN THE VARIOUS HELICOPTER FLIGHT REGIMES.
DIFFICULTIES LIKELY TO BE ENCOUNTERED IN DEVELOPING AN ADEQUATE
HELICOPTER SIMULATION ARE PRESENTED.

METHODS AND PROCEDURES FOR DETERMINING THE ACCURACY TO WHICH
SPECIFIC DYNAMIC RESPONSE PARAMETERS MUST BE SIMULATED ARE
PRESENTED. PILOT SENSITIVITIES ARE DEVELOPED FOR EACH
SIGNIFICANT HANDLING QUALITIES PARAMETER IN EACH FLIGHT REGIME.
THE DYNAMIC ATTRIBUTES OF THE PILOT-AIRCRAFT COMBINATION WITH
REGARD TO EACH SPECIFIC PARAMETER ARE DISCRETELY AND COMPREHEN-
SIVELY DISCUSSED.

A DETAILED DESCRIPTION OF HELICOPTER EQUATIONS OF MOTION,
TRANSFER FUNCTIONS AND MODES OF MOTION ARE PRESENTED. THE
PRACTICAL LIMITATIONS OF VARIOUS METHODS AND PROCEDURES FOR
PROGRAMMING THE EQUATIONS OF MOTION FOR PILOTED FLIGHT
SIMULATION PURPOSES ARE DISCUSSED.

SWANSON, A.M. NOTES ON SIMULATOR INSTRUMENTATION FOR MEASURE-
MENT OF PILOT PROFICIENCY. AIR FORCE PERSONNEL AND TRAINING
RESEARCH CENTER, RANDOLPH AFB, TX., TECH. MEMO. A6L - TM-57-3,
MAY 1967.

* ABSTRACT *

ASSESSMENT OF PILOT PERFORMANCE IN AIRCRAFT AND IN FLIGHT
SIMULATORS IS ACCOMPLISHED ORDINARILY BY HUMAN EVALUATORS,
OBSERVING PERFORMANCE DIRECTLY AND RECORDING OBSERVATIONS ON

PAPER EVALUATION FORMS OR FLIGHT CHECKS. BY EMPLOYING AUTOMATIC RECORDING EQUIPMENT TO RECORD SELECTED INDICES OF PILOT PERFORMANCE DURING FLIGHT, IT MAY BE POSSIBLE TO IMPROVE MEASUREMENT OF PILOT PROFICIENCY IN SEVERAL WAYS: BY PERMITTING, TO SOME EXTENT, THE SUBSTITUTION OF OBJECTIVE MEASURES; BY REDUCING THE LOAD ON THE HUMAN EVALUATOR; AND BY TAPPING SOURCES OF VARIATION IN PILOT PROFICIENCY NOT OBSERVED BY THE HUMAN EVALUATOR.

THE BOMBER CREW RESEARCH UNIT AT CASTLE AIR FORCE BASE OF THE OPERATOR LABORATORY, AIR FORCE PERSONNEL AND TRAINING RESEARCH CENTER, HAS BEGUN AN INVESTIGATION OF THE FEASIBILITY OF OBTAINING PILOT PROFICIENCY MEASURES FROM OSCILLOGRAPHIC RECORDS OF PILOT PERFORMANCE IN THE B-52 SIMULATOR (TYPE S-9). A PHOTON SIX-CHANNEL OSCILLOGRAPH HAS BEEN PURCHASED TO MAKE PRELIMINARY TESTS IN THE INVESTIGATION. THIS PAPER DISCUSSES THE INTEGRATION OF THE RECORDING EQUIPMENT WITH THE FLIGHT SIMULATOR AND THE DEVELOPMENT OF A PLAN FOR OBTAINING APPROPRIATE DATA TO EVALUATE THE UTILITY OF INSTRUMENTATION IN THE MEASUREMENT OF PILOT PERFORMANCE IN THE SIMULATOR. (AUTHOR)

SZALAI, KENNETH J. AEROSPACE ENGINEER, AND DEETS, DWAIN, HEAD, SYSTEMS AND SIMULATION NASA FLIGHT RESEARCH CENTER, EDWARDS, CA

* ABSTRACT *

MOTION AND VISUAL CUE INFLUENCES ON PILOT PERFORMANCE AND OPINION IN ROLL MOTION TASKS WERE INVESTIGATED IN AN AIRBORNE SIMULATOR FLIGHT PROGRAM. HUMAN DESCRIBING FUNCTIONS WERE OBTAINED FROM A COMPENSATORY TRACKING TASK FOR THREE ROLL DAMPING CONDITIONS (LOW, MEDIUM, AND HIGH), AND THREE SIMULATOR CONFIGURATIONS (FULL MOTION-VFR, FULL MOTION-IFR, AND FIXED BASE IFR). DIFFERENCES IN HUMAN RESPONSE ARE INTERPRETED RELATIVE TO MOTION AND VISUAL STIMULI. PILOT REACTION TO THE TRACKING TASK IN TERMS OF ACTUALLY ENCOUNTERED CRUISE TASKS WAS IMPORTANT IN APPLYING THE QUANTITATIVE DATA OBTAINED. IN ADDITION, THE PILOTS CONDUCTED HANDLING-QUALITIES EVALUATIONS OF THE NINE DIFFERENT CASES. THE GROSS EFFECTS OF MOTION AND VISUAL STIMULI, AS DETERMINED BY PILOT COMMENTS AND RATINGS, ARE COMPARED WITH THE CONCLUSIONS DRAWN FROM COMPENSATORY TRACKING TASK RESULTS.

TANG, J., HELD, R., AND YOUNG, L.R., INTERACTION OF VISUALLY INDUCED AND LABYRINTHINE SENSED POSTURAL TILT, PRESENTED AT THE PSYCHONOMIC SOCIETY, BOSTON, MA., NOVEMBER 1974.

NO ABSTRACT YET

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TAYLOR, R.L. AND GERBER, A., ET. AL. 'STUDY TO DETERMINE REQUIREMENTS FOR UNDERGRADUATE PILOT TRAINING RESEARCH SIMULATION SYSTEM'. TECHNICAL REPORT AFHRL-TR-68-11, 13 JANUARY 1969.

* ABSTRACT *

IN ORDER TO PROVIDE A SOUND BASIS FOR THE PREPARATION OF SPECIFICATIONS DEFINING THE REQUIREMENTS FOR THE UNDERGRADUATE PILOT TRAINING RESEARCH SIMULATION SYSTEM (UPTRSS), A COMPREHENSIVE STUDY WAS MADE OF ALL ASPECTS OF CURRENT AND PROJECTED SIMULATOR TECHNOLOGY AND THOSE TECHNIQUES OF SIMULATION AND TRAINING WHICH APPEARED TO OFFER THE GREATEST UTILITY FOR RESEARCH PURPOSES WERE ANALYZED IN DETAIL TO DETERMINE THE FORM AND EXTENT OF THE CAPABILITY IN EACH AREA (E. G. AIRCRAFT SYSTEMS SIMULATION, MOTION SIMULATION, VISUAL SIMULATION) WHICH SHOULD BE SPECIFIED FOR THE FACILITY. TO ASSURE THE AIR FORCE THE WIDEST POSSIBLE LATITUDE IN ITS EVENTUAL SELECTION OF THE EQUIPMENTS TO BE PROVIDED IN THE FACILITY, ALTERNATIVE APPROACHES OF VARYING LEVELS OF COMPLEXITY ARE DESCRIBED IN A NUMBER OF AREAS AND THE TENTATIVE PRELIMINARY DESIGN REQUIREMENTS SET FORTH IN EACH AREA ARE QUALIFIED AS NECESSARY, TO PERMIT THEM TO BE CONSIDERED IN THE LIGHT OF SUBSEQUENT DECISIONS BY THE AIR FORCE REGARDING RESEARCH OBJECTIVES, TRAINING OBJECTIVES, AND LEVEL OF EXPENDITURE.

THOMAS, B.K., JR. 'PILOTS SEE VALUE IN TURBULENCE SIMULATION', AVIATION WEEK AND SPACE TECHNOLOGY, SEPTEMBER 26, 1966.

* ABSTRACT *

FEDERAL AVIATION AGENCY'S DYNAMIC SIMULATION STUDY HERE OF JET TRANSPORT STABILITY CHARACTERISTICS DURING SEVERE TURBULENCE HAS BEEN COMPLETED BY 64 PILOTS WITHOUT ANY LOSSES OF CONTROL OCCURRING.

THE SIMULATED TURBULENCE PENETRATIONS, A TEST SERIES OF WHICH WERE FLOWN BY THIS AVIATION WEEK AND SPACE TECHNOLOGY PILOT ARE CONDUCTED ON THE NAVY AEROSPACE MEDICAL RESEARCH LABORATORY'S 50 FT CENTRIFUGE USING A BOEING 720 COCKPIT MOCKUP MOUNTED ON A HYDRAULIC SHAKE TABLE WITHIN THE CENTRIFUGE GONDOLA. WHILE PERFORMING SIMULATED MANEUVERS, INCLUDING DESCENDING AND CLIMBING TURNS, THE TEST SUBJECTS EXPERIENCE THREE SEVERE TURBULENCE PROFILES DURING AN APPROXIMATELY 30-MIN FLIGHT.

REACTION OF ONE PILOT - 'I CAN RECALL NO OTHER SINGLE EVENT THAT HAS BEEN MORE VALUABLE TO ME AS A PILOT. THE SIMULATION OF TURBULENCE ENCOUNTERS IS EXTREMELY REALISTIC IN THE CENTRIFUGE. THE BOEING 720 COCKPIT IS ADEQUATE, AND THE CONTROL FORCES, RESPONSE AND STABILITY OF THE CAPSULE ARE REMARKABLY REPRESENTATIVE OF THE ACTUAL AIRCRAFT.' THE PILOT

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CITED TWO MAJOR BENEFITS FROM HIS PARTICIPATING IN THE STUDY: VERIFICATION OF THE SOUNDNESS OF PRESENTLY PUBLISHED SEVERE TURBULENCE PENETRATION TECHNIQUES AND THE CONFIDENCE GAINED BY APPLYING THESE TECHNIQUES AND MAINTAINING CONTROL THROUGHOUT THE SEVERE TURBULENCE.

TIESLER, G. 'THE PERCEPTION OF MOTION IN VEHICLE SIMULATORS'. FOREIGN TECHNOLOGY DIVISION, WRIGHT-PATTERSON AFB, OHIO. REPORT NO. FTD-HC-23-2782-74. NOVEMBER 1974. AD 8001 563L.

* ABSTRACT *

THIS LITERATURE GIVES A SHORT REVIEW ON PHYSIOLOGY OF MOTION PERCEPTION, AS WELL AS THE RESULTING REQUIREMENTS FOR MOTION SIMULATION. SEVERAL EXAMPLES OF SIMULATORS ARE USED TO POINT OUT THE NECESSITY OF ADAPTING SIMULATION CAPABILITIES TO SPECIFIC RESEARCH AND TRAINING PROBLEMS. ALSO, THE PROBLEM OF INTERACTIONS BETWEEN VISUAL AND MOTION CUES IS DEMONSTRATED. SOME EXAMPLES FROM BIOCYBERNETICS ILLUSTRATE THE COMPLEX PROCESSING CUES IN MAN.

TOLER, J.R., MCINTYRE, W., COFFEE, M.P. SIMULATION OF HELICOPTER AND V/STOL AIRCRAFT VOLUME I, HELICOPTER ANALYSIS REPORT. STUDY, EQUATIONS OF MOTION OF VERTICAL, SHORT TAKE-OFF AND LANDING OPERATIONAL FLIGHT/WEAPON SYSTEM TRAINERS. MELPAR INC. FOR THE NAVAL TRAINING DEVICE CENTER, PORT WASHINGTON, N.Y. NAVTRADEVNEN TECHNICAL REPORT 1205-1, SEPTEMBER 1963.

* ABSTRACT *

THIS REPORT IS THE PRODUCT OF A STUDY PROGRAM DESIGNED TO DEVELOP THE EQUATIONS OF MOTION OF A HELICOPTER IN A FORM SUITABLE FOR SIMULATION USING EITHER AN ANALOG OR A DIGITAL COMPUTER. THE OBJECTIVE OF THE REPORT IS TO PRESENT THE AERODYNAMIC AND DYNAMIC HELICOPTER EQUATIONS SUPPORTED BY DERIVATIONS AND A COMPREHENSIVE DISCUSSION.

THE AERODYNAMIC EQUATIONS ARE DEVELOPED THROUGH A MODIFIED BLADE ELEMENT APPROACH ALTHOUGH OTHER ALTERNATIVE TECHNIQUES ARE CONSIDERED. THE EQUATIONS ARE NOT CONSTRAINED TO A GIVEN, OR A NUMBER OF GIVEN, FLIGHT CONDITIONS BUT ARE VALID FOR THE ENTIRE FLIGHT REGIME INCLUDING HOVER, TRANSITION, AUTOROTATION, THE EFFECTS OF VARYING ALTITUDE, GROUND EFFECTS, AND BLADE AEROELASTICITY IN TWIST.

THE DYNAMIC DERIVATION DEVELOPS A SET OF UNABRIDGED AND SIMPLIFIED EQUATIONS OF TRANSLATIONAL AND ANGULAR RATES SPECIFICALLY FOR A TANDEM-ROTOR HELICOPTER. THE DYNAMIC AND AERODYNAMIC EFFECTS ON THE HELICOPTER ROTOR ARE COMBINED TO PRODUCE EQUATIONS TO DESCRIBE BLADE ACCELERATION, VELOCITY, AND

POSITION, WHILE FLAPPING, AT CHOSEN POINTS DURING A ROTATION.

A TECHNIQUE IS ALSO PRESENTED FOR GREATLY SIMPLIFYING THE SIMULATION OF A TANDEM-ROTOR HELICOPTER WHICH ELIMINATES THE NECESSITY OF CONSTRUCTING DETAILED, IDENTICAL MATHEMATICAL MODELS FOR THE TWO ROTORS.

THE EQUATIONS DEVELOPED AND PRESENTED WITHIN THE REPORT HAVE BEEN USED TO CREATE A COMPLETE MATHEMATICAL MODEL OF BOTH A SINGLE-ROTOR AND A TANDEM-ROTOR HELICOPTER AND PROGRAMMED ON A 7090 DIGITAL COMPUTER OVER A WIDE RANGE OF FLIGHT CONDITIONS, AND THE RESULTS WERE VERIFIED.

TOMLISON, L.R. DISCUSSION OF MOTION SIMULATOR REQUIREMENTS. 1
BRIEFING DOCUMENT NO. D6-17755 TN, JUNE 1965.

NO ABSTRACT GIVEN

TREISMAN, M. MOTION SICKNESS: AN EVOLUTIONARY HYPOTHESIS. SCI-
ENCE, VOL. 197, 29 JULY 1977, PP. 493-495.

* ABSTRACT *

SINCE THE OCCURRENCE OF VOMITING AS A RESPONSE TO MOTION IS BOTH WIDESPREAD AND APPARENTLY DISADVANTAGEOUS, IT PRESENTS A PROBLEM FOR EVOLUTIONARY THEORY. AN HYPOTHESIS IS PROPOSED SUGGESTING THAT MOTION SICKNESS IS TRIGGERED BY DIFFICULTIES WHICH ARISE IN THE PROGRAMMING OF MOVEMENTS OF THE EYES OR HEAD WHEN THE RELATIONS BETWEEN THE SPATIAL FRAMEWORKS DEFINED BY THE VISUAL, VESTIBULAR, OR PROPRIOCEPTIVE INPUTS ARE REPEATEDLY AND UNPREDICTABLY PERTURBED. SUCH PERTURBATIONS MAY BE PRODUCED BY CERTAIN TYPES OF MOTION, OR BY DISBURBANCES IN SENSORY INPUT OR MOTOR CONTROL PRODUCED BY INGESTED TOXINS. THE LAST WOULD BE THE IMPORTANT CAUSE IN NATURE, THE MAIN FUNCTION OF THE EMESIS BEING TO RID THE INDIVIDUAL OF INGESTED NEURO-TOXINS. ITS OCCURRENCE IN RESPONSE TO MOTION WOULD BE AN ACCIDENTAL BY-PRODUCT OF THIS SYSTEM.

REMELAY, H.G., BROWN, W.L. AND FUTTERWEIT, A. APPLICATION OF HARMONIC ANALYSIS IN A STUDY OF TRACKING PERFORMANCE IN THE TV-2 AIRCRAFT AND IN CENTRIFUGE AND STATIONARY SIMULATIONS OF THAT AIRCRAFT. U.S. NAVAL AIR DEVELOPMENT CENTER, JOHNSVILLE, REPORT NADC-AC-6406. 1964.

* ABSTRACT *

PILOTING PERFORMANCE IN A CONTINUOUS TRACKING TASK WAS STUDIED

IN AN AIRCRAFT, IN HUMAN CENTRIFUGE SIMULATIONS CONTROLLED BY A COMPUTER SIMULATION OF THE AIRCRAFT, AND IN A STATIONARY SIMULATION. CONTINUOUS RECORDS OF ELEVATOR AND AILERON CONTROL SURFACE DEFLECTIONS WERE SUBJECTED TO A POWER SPECTRAL DENSITY ANALYSIS. RESULTS INDICATE THAT THERE IS A REDUCTION IN THE CONTRIBUTIONS OF HIGH FREQUENCY COMPONENTS OF POWER, SUCCESSIVELY, FROM THE STATIC SIMULATION TO THE CENTRIFUGE SIMULATIONS, TO THE AIRCRAFT ITSELF. THE POWER SPECTRAL DENSITY FUNCTION FOR PERFORMANCE IN A CENTRIFUGE SIMULATION IS MORE LIKE THAT FOR THE AIRCRAFT THAN IS THE POWER SPECTRAL DENSITY FUNCTION IN A STATIC SIMULATION.

TURNER, L. A REVIEW OF THE EFFECTS OF VIBRATION ON PERFORMANCE. AMRL MEMORANDUM REPORT P-18, OCTOBER 1962.

ABSTRACT NOT AVAILABLE AT TIME OF PUBLICATION

VALVERDE, F.H. FLIGHT SIMULATORS, A REVIEW OF THE RESEARCH AND DEVELOPMENT. WRIGHT-PATTERSON AFB, OHIO: AEROSPACE MEDICAL RESEARCH LABORATORY, AEROSPACE MEDICAL DIVISION, JULY 1968, TECHNICAL REPORT AMRL-TR-68-97.

* ABSTRACT *
THIS REPORT PRESENTS A GENERAL REVIEW OF THE RESEARCH AND DEVELOPMENT OF FLIGHT SIMULATORS AND RELATED AREAS SPONSORED BY MILITARY AND OTHER GOVERNMENT AGENCIES SINCE 1949. THE USE OF SIMULATORS FOR FLIGHT TRAINING IS EMPHASIZED. THE REPORT DOES NOT CONSIDER MATHEMATICAL MODELS AND SPACE FLIGHT SIMULATORS. THE TOPICS INCLUDE (1) VISUAL AND MOTION SIMULATION, (2) TRANSFER OF TRAINING, (3) UTILIZATION AND EVALUATION AND (4) COMPUTERS. AN ANNOTATED BIBLIOGRAPHY OF UNCLASSIFIED TECHNICAL REPORTS REVIEWED IS INCLUDED FOR EACH OF THE TOPICS. THE DEFENSE DOCUMENTATION CENTER ACCESSION NUMBER FOR EACH REPORT IS PROVIDED TO FACILITATE THE ACQUISITION OF MICROFILM COPIES OF DESIRED DOCUMENTS BY UNITED STATES MILITARY AND OTHER GOVERNMENT AGENCIES.

VALVERDE, F.H. A REVIEW OF FLIGHT SIMULATOR TRANSFER OF TRAINING STUDIES. ADVANCED SYSTEMS DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, WRIGHT-PATTERSON AIR FORCE BASE, OHIO. IN 'HUMAN FACTORS', 1973, VOL 15 (6), PAGES 510-523.

* ABSTRACT *
AFTER OPERATIONAL EQUIPMENT IS CONSIDERED TO BE THE MOST EFFECTIVE AND VALID TRAINING EQUIPMENT. HOWEVER, THIS IS NOT

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TRUE IN EVERY INSTANCE. IN FACT, SOMETIMES IT MAY BE UNDESIRABLE TO USE REAL EQUIPMENT FOR TRAINING IF SUITABLE SIMULATORS ARE AVAILABLE. FOR EXAMPLE, THE USE OF OPERATIONAL EQUIPMENT HAS SEVERAL DISADVANTAGES WHICH INCLUDE (1) HIGH COST (2) LIMITATION ON PRACTICE OF VARIOUS ASPECTS OF, AND (3) SAFETY. PRACTICAL DECISIONS IN THE USE OF TRAINING DEVICES DEPEND UPON COMPROMISES BETWEEN ECONOMIC AND TRAINING OBJECTIVES. A TRAINER NEED NOT DUPLICATE OPERATIONAL EQUIPMENT TO HAVE TRAINING VALUE. TECHNICAL REPORTS PERTAINING TO FLIGHT SIMULATOR TRANSFER OF TRAINING STUDIES AVAILABLE FROM THE DEFENSE DOCUMENTATION CENTER ARE REVIEWED.

VARBLE, A.E.

EVALUATION OF SIMULATOR TRAINING FOR AIRCREWS IN CCT AIR-TO-AIR MANEUVERS. USAF TACTICAL AIR COMMAND OPERATIONS ANALYSIS REPORT NO. 72-5 USAF, HQ TAC, LANGLEY AFB, VIRGINIA, FEBRUARY 1972.

* ABSTRACT *

A TACTICAL AIR COMMAND PROJECT EVALUATED THE USEFULNESS AND VALIDITY OF SIMULATOR INSTRUCTION OF BASIC FLIGHT MANEUVERS/AIR COMBAT MANEUVERS PRIOR TO STUDENT TRAINING IN THE AIR. A TEST GROUP OF EIGHT STUDENTS RECEIVED FOUR HOURS OF SIMULATOR INSTRUCTION AND THEN RECEIVED THE NINE STUDENTS OF THE CONTROL GROUP TO COMPLETE THE AIRWORK PHASE. RESULTS OF THE QUANTITATIVE AND SUBJECTIVE EVALUATION ARE:

GRADE ANALYSIS. THE AVERAGE GRADES OF THE TEST GROUP WERE BETTER THAN THE GRADES OF THE CONTROL GROUP. TEST GROUP PERFORMANCE IN THE OFFENSIVE MANEUVERS WAS SUPERIOR TO THAT OF THE CONTROL GROUP, WHEREAS, DEFENSIVELY, BOTH GROUPS WERE NEARLY EQUAL.

INSTRUCTOR PILOT VIEWS-GENERALLY, THE INSTRUCTOR PILOTS BELIEVED THAT THE STUDENTS IN THE TEST GROUP HAD A MUCH BETTER CONCEPT OF AIR-TO-AIR COMBAT MANEUVERING THAN DID THOSE STUDENTS IN THE CONTROL GROUP.

TEST STUDENT VIEWS - THE DMS INSTRUCTION IMPARTED A SENSE OF SUPERIOR CAPABILITY OF THE STUDENTS THAT WAS NOT JUSTIFIED BY PERFORMANCE. AS A GROUP, ALL STUDENTS BELIEVED THE SIMULATOR INSTRUCTION TO BE BENEFICIAL.

OVERALL. AN AIR-TO-AIR SIMULATOR OF THE DMS TYPE MAY BE AN EFFECTIVE TRAINING AID FOR STUDENT AIRCRAFT COMMANDERS.

VöGL, E. 'DIFFERENCES BETWEEN SIMULATION AND REAL WORLD AT THE IARG AIR TO AIR COMBAT SIMULATOR WITH A WIDE ANGLE VISUAL SYSTEM'. PRESENTED AT AGARD FLIGHT MECHANICS PANEL SPECIALISTS' MEETING ON PILOTED AIRCRAFT ENVIRONMENT SIMULATION TECHNIQUES, BRUSSELS, BELGIUM, APRIL 24-27, 1978.

* ABSTRACT *

THE INDUSTRIEANLAGEN-BETRIEBSGESELLSCHAFT IN OTTOBRUNN NEAR MUNICH HAS BUILT AN AIR TO AIR COMBAT SIMULATOR.

THERE ARE TWO COCKPITS, EACH INSIDE A SPHERICAL SCREEN OF 12 M DIAMETER, WHICH SURROUNDS EACH COCKPIT WITH A SOLID ANGLE OF EIGHTY FIVE PER CENT OF FOUR PI.

FOR AIR TO AIR COMBAT SIMULATION IT IS VERY DIFFICULT TO INSTALL A CORRECT OPERATING MOTION SYSTEM. SINCE THE PILOTS FLY FREQUENTLY ALTERNATING HIGH 'G' LOADS AND FREQUENTLY ALTERNATING ROLL ACCELERATIONS THE MOTION SYSTEM WOULD GET INTO 'WASH OUT' FUNCTION QUICKLY. THE MOTION SYSTEM WOULD BE UNABLE TO OPERATE CORRECTLY. THEREFORE, WE HAVE NO MOTION SYSTEM, BUT A BUFFETING SYSTEM AND A CORRECTLY OPERATING G-SUIT TO OFFER A 'G' CUE TO THE PILOTS. THIS EFFECT IS INTENSIFIED BY 'GREY OUT/BLACK OUT' SIMULATION. 'GREY OUT/BLACK OUT' IS REPRESENTED BY DIMMING ALL PROJECTORS AND ILLUMINATION OF INSTRUMENTS AS A FUNCTION OF TIME AT HIGH 'G'S'. THE CYCLE TIME FOR ALL HARDWARE SERVOS IS LOWER THAN FIFTY MILLISECONDS AND ALL SERVOS ARE SO DESIGNED TO HAVE THE PERFORMANCE FOR THE REQUIRED VELOCITIES AND ACCELERATIONS OF MODERN FIGHTERS.

VöGT, L.H., KRAUSE, H.E., HOHLWECK, H., AND MAY, E. MECHANICAL IMPEDANCE OF SUPINE HUMANS UNDER SUSTAINED ACCELERATION. 'AERO-SPACE MEDICINE', 44, 2: 123-128, 1973.

* ABSTRACT *

MEASUREMENTS OF THE MECHANICAL IMPEDANCE OF THE SUPINE HUMAN BODY WERE CONDUCTED TO INVESTIGATE THE NONLINEARITIES OF THE BODY SYSTEM. A HYDRAULICALLY DRIVEN SHAKE TABLE WAS INSTALLED ON A CENTRIFUGE. TRANSMITTED FORCE AND THE ACCELERATION OF THE PLATFORM, ON WHICH THE SUBJECTS WERE LYING, WERE RECORDED IN THE FREQUENCY RANGE OF 2HZ-20HZ. SINUSOIDAL ACCELERATION AMPLITUDE WAS HELD CONSTANT AT 0.5G. THE IMPEDANCE AND PHASE RESULTS SHOW THAT SUSTAINED ACCELERATION UP TO +5G-X STIFFENS THE HUMAN BODY WITH INCREASING G-X AND SHIFTS THE RESONANCE FREQUENCY FROM 6HZ UNDER NORMAL GRAVITY TO 8HZ UNDER +2G-X AND FURTHER UP TO 11HZ, 13HZ AND 15HZ UNDER +3G-X, +4G-X AND 5G-X RESPECTIVELY. THE MODULUS OF IMPEDANCE GROWS WITH CENTRIFUGE ACCELERATION. TO EXPLAIN THESE FINDINGS A MULTI-DEGREE-OF-FREEDOM MODEL IS PROPOSED. ITS MODEL PARAMETERS WERE COMPUTED BY WAY OF AN OPTIMIZATION PROCEDURE. THE BEHAVIOR OF THE MODEL UNDER SUSTAINED ACCELERATION SHOWS AN INCREASE OF THE EFFECTIVE

MASSSES NEAR THE DRIVING POINT AT THE EXPENSE OF THE UPPER MASSSES. THE SPRING CONSTANTS OF THE SUBSYSTEM NEAR THE DRIVING POINT INCREASE WITH $+G-X$. THE DAMPING COEFFICIENTS DEPEND ON MASS AND SUSTAINED ACCELERATION. THESE RESULTS SHOW THAT THE HUMAN BODY BEHAVES NONLINEARLY IN AN EXTREME DYNAMIC ENVIRONMENT. AN EXPANSION OF THE PROPOSED MODEL TO GREATER COMPLEXITY IS NECESSARY TO EXPLAIN ITS REACTIONS TO FORCES FROM OTHER DIRECTIONS AND TO TRANSIENTS.

VASS, H.A. 'FIDELITY OF SIMULATION AND PILOT PERFORMANCE'. TRAINING DEVICE DEVELOPMENTS. NAVTRADEVEN P-1300-46, FEBRUARY 1969 (A) PP. 5-12

* ABSTRACT *

IN 1963, AN EXPERIMENTAL PROGRAM WAS STARTED TO PROVIDE INFORMATION ON FIDELITY OF SIMULATION AND ITS RELATION TO TRANSFER OF TRAINING EFFECTS. DATA WERE COLLECTED OVER A PERIOD OF FOUR YEARS USING THE UNIVERSAL DIGITAL OPERATIONAL FLIGHT TRAINER T88L (UDOFFT) AS THE RESEARCH VEHICLE.

THE AIRCRAFT SIMULATED IN THE EXPERIMENTS WAS A HIGH PERFORMANCE SINGLE ENGINE, JET FIGHTER. THE SIMULATOR WAS FIXED BASE (NO MOTION PLATFORM).

THE FINDINGS OF PHASES 1 THRU 4 SERIOUSLY QUESTION THE ASSUMPTION THAT THE BEST SIMULATOR FOR TRAINING PURPOSES IS THE ONE THAT BEARS THE CLOSEST PHYSICAL RESEMBLANCE TO THE AIRCRAFT. UNDER RIGOROUSLY CONTROLLED EXPERIMENTAL PROCEDURES AND USING PILOT PERFORMANCE AS THE PRIMARY CRITERION MEASURE, BOTH JET AND NON-JET PILOTS TRANSFERRED SUCCESSFULLY TO FULL SIMULATION CONDITIONS AFTER TRAINING ON GREATLY REDUCED CONDITIONS. MOREOVER, THE PILOTS WERE UNABLE TO DISCRIMINATE BETWEEN THE VARYING SIMULATION CONDITIONS. THESE FINDINGS IN THEMSELVES ARE SUGGESTIVE OF SIGNIFICANT COST REDUCTIONS IN THE HARDWARE AND SOFTWARE ASPECTS OF OBT DEVELOPMENT. WHEN RELATED TO THE EFFECTIVE TIME CONSTANT CONSTRUCT, IT APPEARS LIKELY THAT FURTHER LABORATORY EXPERIMENTATION IN THIS AREA WILL LEAD TO A NEW APPROACH TO PERCEPTUAL FIDELITY OF SIMULATION IN THE OBT. IT SHOULD ALSO BE NOTED THAT THESE FINDINGS ARE NOT LIMITED TO AIRCRAFT SIMULATION BUT APPLY TO ANY VEHICLE SIMULATION FOR TRAINING PURPOSES.

THE FEASIBILITY TEST OF ADAPTIVE TRAINING WAS A FIRST IN THAT NO OBT HAD PREVIOUSLY BEEN PROGRAMMED FOR THIS ADVANCED TRAINING TECHNOLOGY. IT IS LIKELY THAT COMPUTER CONTROLLED ADAPTIVE TRAINING WILL BE A TYPICAL FEATURE OF FUTURE FLIGHT TRAINERS. IN FACT, DEVICE 2824, THE FIRST UNIT OF THE ARMY SYNTHETIC FLIGHT SYSTEM, INCORPORATES THIS FEATURE.

FINALLY, THE SUCCESSFUL USE OF THE AUDIO-VISUAL TRAINER IN TEACHING JET COCKPIT INSTRUMENTATION POINTS THE WAY TO THE

DEVELOPMENT OF SIMILAR INEXPENSIVE DEVICES FOR EARLY STAGES
OF TRAINING IN VEHICLE CONTROL.

WAAG, W.L., EDDOWES, E.E., FULLER, H.H. AND FULLER, R.R.
ASUPT AUTOMATED OBJECTIVE PERFORMANCE SYSTEM, AFHRL-TR-75-3,
WILLIAMS AFB ARIZONA: FLYING TRAINING DIVISION, DECEMBER 1974

* ABSTRACT *

TO REALIZE ITS FULL RESEARCH POTENTIAL, A NEED EXISTS FOR THE
DEVELOPMENT OF AN AUTOMATED OBJECTIVE PILOT PERFORMANCE EVALUA-
TION SYSTEM FOR USE IN THE ADVANCED SIMULATION IN UNDERGRADUATE
PILOT TRAINING (ASUPT) FACILITY. THE PRESENT REPORT DOCUMENTS
THE APPROACH TAKEN FOR THE DEVELOPMENT OF PERFORMANCE MEASURES
AND ALSO PRESENTS DATA COLLECTED FROM TWO PRELIMINARY EVALUATION
STUDIES. THE RESULTS INDICATED THAT THE OBJECTIVELY DERIVED
MEASURES: (1) CORRELATE HIGHLY WITH INSTRUCTOR RATINGS, AND
(2) DISCRIMINATE BETWEEN PILOTS OF DIFFERENT EXPERIENCE LEVELS.
THESE FINDINGS ARE ENCOURAGING AND DEMONSTRATE THE POTENTIAL OF
THE PRESENT APPROACH FOR GENERATING THE NEEDED AUTOMATED
OBJECTIVE PILOT PERFORMANCE MEASUREMENT SYSTEM.

WALKER, L.A. AND GALLOWAY, R. FLIGHT FIDELITY EVALUATION OF
THE T-2C OPERATIONAL FLIGHT TRAINER, DEVICE 2F101. NAVAL AIR
TEST CENTER, PATUXENT, RIVER, MD. REPORT NO. NATC-FT-3R-75
AD BOC4 862L, JANUARY 1975.

* ABSTRACT *

A FLIGHT FIDELITY EVALUATION OF THE T-2C OPERATIONAL FLIGHT
TRAINER, DEVICE 2F101, WAS CONDUCTED FOR THE OPERATIONAL FLIGHT
TRAINER MISSION. THIS REPORT PRESENTS THE CULMINATION OF THE
FLYING QUALITIES, PERFORMANCE AND MOTION BASE CUES DEVELOPMENTAL
EFFORT, AND IS CHARACTERISTIC OF THE 2F101 UNIT NO. 1 DURING
FINAL IN-PLANT TESTING AND AS INSTALLED AT NAS CHASE FIELD. THE
T-2C OPERATIONAL FLIGHT TRAINER EXHIBITED OUTSTANDING POTENTIAL,
BUT CANNOT, AS TESTED, SATISFACTORILY PERFORM OFT MISSIONS DUE
TO CONTROL SYSTEM RELIABILITY PROBLEMS.

WALLACH, F.
THE PERCEPTION OF MOTION.
SCIENTIFIC AMERICAN, VOL. 201, 1, JULY 1959.

* ABSTRACT *

A SERIES OF RELATIVE MOTION EXPERIMENTS IS DESCRIBED TO
ILLUSTRATE HOW OUR VISUAL PERCEPTION OF MOTION MAY RESULT IN
VISUAL ILLUSIONS. THE VISUALLY INDUCED SENSATION OF LOCOMOTION

SEEMS INDISTINGUISHABLE FROM THAT WHICH ARISES FROM KINESTHETIC STIMULI AND ON THESE OCCASIONS OVERWHELMS THEM. IN ALLOCATING THE QUALITIES OF MOTION AND OF REST TO OURSELVES AND OUR ENVIRONMENT, VISUAL PERCEPTION FOLLOWS THE RULE THAT KEEPS THE SURROUNDING AT REST AND BESTOWS MOTION UPON THE OBJECT SURROUNDED.

WAMNER, F.E. CAPABILITIES OF MOTION PLATFORMS FOR FLIGHT SIMULATORS. NAVAL TRAINING EQUIPMENT CENTER, AIR WARFARE DEPARTMENT, JANUARY 1971.

* ABSTRACT *

MOTION SIMULATION HAS BECOME AN IMPORTANT FEATURE OF CURRENT FLIGHT SIMULATORS AND OPERATIONAL FLIGHT TRAINERS. THIS REPORT PRESENTS THE CAPABILITIES AND REQUIREMENTS OF MOTION SIMULATION SYSTEMS WHICH HAVE BEEN OR ARE CURRENTLY BEING PROCURED BY NAVTRAEVCEN. IT IS INTENDED THAT THIS REPORT WILL BE CONTINUALLY UPDATED SO AS TO ALWAYS BE REPRESENTATIVE OF THE AVAILABLE STATE OF THE ART IN COCKPIT MOTION.

WARGO, V.
PENNSYLVANIA ELECTRONICS PRODUCTS, INC.
'THE UDBFT FLIGHT SIMULATION SYSTEM.'
ANRL-TR 63-133.
6570TH AEROSPACE MEDICAL RESEARCH LABORATORIES
WRIGHT-PATTERSON AFB, OHIO
1963.

* ABSTRACT *

UDBFT (UNIVERSAL DIGITAL OPERATIONAL FLIGHT TRAINER) REPRESENTS THE FIRST FULL-SCALE APPLICATION OF A HIGH-SPEED, GENERAL PURPOSE DIGITAL COMPUTER TO THE REAL-TIME FLIGHT SIMULATION PROBLEM. THROUGH THE USE OF THE STORED PROGRAM DIGITAL COMPUTER, SIMULATION OF DIFFERENT AIRCRAFT IS ACCOMPLISHED BY CHANGING THE COMPUTER PROGRAM. THIS FLEXIBILITY IS THE KEY TO THE REALIZATION OF THE FULL ADVANTAGES OF THE DIGITAL CONTROL SYSTEM AS COMPARED TO THE CONVENTIONAL ANALOG CONTROL SYSTEM IN THIS APPLICATION. BASICALLY, A HIGH-SPEED GENERAL PURPOSE DIGITAL COMPUTER, THE UDBFT COMPUTER REPRESENTS AN ADVANCEMENT IN THE DESIGN OF REAL-TIME CONTROL COMPUTERS. WITH THE USE OF DUAL, 4096-WORD, RANDOM ACCESS, MAGNETIC CORE MEMORIES, THE BASIC INSTRUCTION TIME FOR THE UDBFT COMPUTER IS FIVE MICROSECONDS. TO INTERFACE WITH THE ANALOG ENVIRONMENT OF A FLIGHT COMPARTMENT, THE UDBFT COMPUTER IS EQUIPPED WITH A SPECIAL-PURPOSE, REAL-TIME INPUT-OUTPUT CAPABILITY. USE OF THE COMPUTER IN A SIMULATION SYSTEM DEMANDED THE PREPARATION OF PROGRAMS FOR APPLYING THE COMPUTER TO THE SOLUTION OF THE MATHEMATICAL MODEL OF THE REAL WORLD SYSTEM UNDER CONSIDERATION. SUCH PROGRAMS WERE WRITTEN

FOR THE F-100A AND THE F9F-2. EXTENSIVE QUALIFICATION TESTING WAS PERFORMED TO ENSURE PROPER AND COMPLETE SIMULATION OF THESE AIRCRAFT.

WARREN, D.H. AND CLEAVER, W.T. VISUAL-PROPRIOCEPTIVE INTERACTION UNDER LARGE AMOUNTS OF CONFLICT. J. OF EXPERIMENTAL PSYCHOLOGY, 80, '2', 1971, 206-214.

* ABSTRACT *

THE DEGREE OF DEPENDENCE OF 120 HUMAN ADULT SS ON VISUAL AND PROPRIOCEPTIVE INFORMATION WAS ASSESSED UNDER CONDITIONS IN WHICH SS RECEIVED DISCREPANT INFORMATION ABOUT THE AZIMUTH POSITION OF A TARGET. BIAS EFFECTS BETWEEN THE TWO MODALITIES WERE MEASURED OVER A WIDE RANGE OF INTRODUCED DISCREPANCY. AS WAS EXPECTED, BOTH BIAS EFFECTS DECREASED WITH INCREASING DISCREPANCY BETWEEN VISION AND PROPRIOCEPTION. HOWEVER, SIGNIFICANT BIAS EFFECTS OCCURRED EVEN AT 60 DEGREES DISCREPANCY. AN EXPLANATION INVOLVING SENSORITONIC EFFECTS WAS EXPLORED. BOTH VISUAL AND POINTING RESPONSES WERE STUDIED, AND A POTENTIAL EFFECT SUGGESTED BY PREVIOUS WORK WAS SUPPORTED. FOR BOTH RESPONSE TYPES, PROPRIOCEPTIVE INFORMATION WAS MORE BIASING AND LESS BIASED THAN PREVIOUSLY HAD BEEN FOUND. THIS DIFFERENCE WAS DISCUSSED IN RELATION TO THE MORE ACTIVE PROPRIOCEPTIVE TARGETING METHOD USED IN THIS EXPERIMENT.

WARTON, L.H.
A FOUR DEGREES OF FREEDOM COCKPIT MOTION MACHINE FOR FLIGHT SIMULATION. ROYAL AIRCRAFT ESTABLISHMENT TECHNICAL REPORT 72075 RECEIVED FOR PRINTING APRIL 1972.

* ABSTRACT *

THIS REPORT GIVES A DETAILED ACCOUNT OF THE DEVELOPMENT OF A MACHINE FOR REPRODUCING AIRCRAFT MOTIONS ON A FLIGHT SIMULATOR COCKPIT.

THE FOUR FREEDOMS OF THE MACHINE ARE ACTUATED BY HYDRAULIC SERVOS.

THE EQUIPMENT IS PART OF THE PILOTED FLIGHT SIMULATOR USED FOR RESEARCH AND DEVELOPMENT STUDIES IN THE AERODYNAMICS DEPARTMENT OF THE ROYAL AIRCRAFT ESTABLISHMENT AT BEDFORD.

THE INFORMATION PRESENTED CONCERNS THE ENGINEERING DESIGN AND SERVO DRIVE CONSIDERATIONS INVOLVED.

A DESCRIPTION IS GIVEN OF THE CONTROL AND SAFETY PROCEDURES USED WHEN OPERATING THE MACHINE WITHIN THE SIMULATOR FACILITY.

THE LIMITATIONS OF THE PERFORMANCE ACHIEVED ARE DISCUSSED BOTH WITH A VIEW TO FINDING WAYS TO IMPROVE THE EXISTING MACHINE, AND TO POINT OUT THOSE PARTICULAR ASPECTS OF DESIGN WHICH NEED CAREFUL ATTENTION AND UNCOMPROMISING IMPLEMENTATION ON ANY FUTURE PROJECT.

WATERS, B.K., GRUNZKE, F.M., IRISH, P.A. AND FULLER, J.H.
PRELIMINARY INVESTIGATION OF MOTION, VISUAL AND G-SEAT EFFECTS
IN THE ADVANCED SIMULATOR FOR UNDERGRADUATE PILOT TRAINING
(ASLPT)
AFRL, WILLIAMS AFB, ARIZONA. SUBMITTED TO THE AIAA VISUAL AND
MOTION SIMULATION CONFERENCE APRIL 26-28, 1976

* ABSTRACT *

THIS STUDY EVALUATED MOTION, FIELD OF VIEW (FOV) AND G-SEAT FACTORS IN ASLPT UNDER VARYING ENVIRONMENTAL CONDITIONS. FIVE MANEUVERS WERE FLOWN BY THREE EXPERIENCED T-37 INSTRUCTOR PILOTS. EACH SUBJECT FLEW 72 TAKEOFFS, GROUND CONTROLLED APPROACHES (GCA) AND LANDINGS AND 360 DEGREES OVERHEAD TRAFFIC PATTERN AND LANDINGS PLUS 27 SLOW FLIGHTS AND AILERON ROLLS. SIXTY-THREE DEPENDENT VARIABLES WERE MEASURED USING AUTOMATED PERFORMANCE MEASUREMENT ON BOTH SYSTEM OUTPUTS AND PILOT INPUTS. SYSTEM PERFORMANCE WAS SIGNIFICANTLY BETTER WITH NO MOTION VS. EITHER 3 DEGREES OR 6 DEGREES OF FREEDOM MOTION. PILOT INPUTS WERE SIGNIFICANTLY SMOOTHER UNDER NO MOTION CONDITIONS. PERFORMANCE UNDER A 150 DEGREE X 300 DEGREE FOV WAS SIGNIFICANTLY BETTER THAN UNDER A 36 DEGREE X 48 DEGREE FOV. THE G-SEAT IMPROVED PERFORMANCE CONSISTENTLY, PARTICULARLY UNDER THE LIMITED FOV. SIGNIFICANT FIRST ORDER INTERACTIONS EMERGED BETWEEN FOV AND G-SEAT FACTORS WITH THE G SEAT MOST BENEFICIAL TO SYSTEM OUTPUT MEASURES WHEN THE LIMITED FOV WAS PRESENT. TWO CEILING/VISIBILITY X G-SEAT INTERACTIONS RELATED TO PITCH CONTROL AND TWO MOTION X FOV X G-SEAT SHOWED CONSISTENTLY SIGNIFICANT RESULTS. STRONG, CONSISTENT INTERSUBJECT PERFORMANCE DIFFERENCES BETWEEN THE EXPERIENCED PILOT SUBJECTS EMERGED ON BOTH PILOT INPUT AND SYSTEM OUTPUT MEASURES.

WATKINSON, D.T., BONDURANT, R.A. AND FREARSON, D.E. DEVELOPMENT
OF A V/STOL MULTI-CREW RESEARCH SIMULATOR. AIAA VISUAL AND
MOTION SIMULATION TECHNOLOGY CONFERENCE PAPER 70-356, CAPE CA.
NAVAL, FL, MAR 16-18, 1970.

* ABSTRACT *

THE FULL TASK RESEARCH SIMULATOR PLAYS AN IMPORTANT ROLE IN THE CREATION OF SOLUTIONS TO CONTROL-DISPLAY PROBLEMS BY PROVIDING THE ESSENTIAL MEANS OF MEASURING THE EFFECTS OF CHANGE OF ONE ELEMENT UPON THE TOTAL PROBLEM WHILE OPERATING UNDER REALISTIC CONDITIONS. SUCH A SIMULATOR WAS RECENTLY DEVELOPED BY THE

AIR FORCE FLIGHT DYNAMICS LABORATORY FOR INITIAL APPLICATION TOWARD SOLUTION OF THE V/STOL IFR CONTROL-DISPLAY PROBLEM. CONSISTING OF A C-135B COCKPIT, THREE DEGREE OF FREEDOM MOTION SYSTEM, TELEVISION VISUAL DISPLAY, DIGITAL COMPUTER, AND AN EXPERIMENTER'S CONTROL CONSOLE, THE SIMULATOR IS THOUGHT TO BE UNIQUE IN ITS CAPABILITY TO INVESTIGATE THE CONTROL-DISPLAY PROBLEMS. INITIAL CHECKOUT AND SAMPLE STUDIES, CONDUCTED PRIMARILY TO PROVIDE A BASELINE OF SIMULATOR PERFORMANCE, HAVE DEMONSTRATED THIS CAPABILITY. HOWEVER, THERE REMAINS A DEFINITE NEED TO QUANTIFY THE EFFECTS OF THE VISUAL AND MOTION CUES UPON THE V/STOL FLIGHT TASK. (AUTHOR)

WEENER, E.F.
THE EFFECT OF SIMULATOR DYNAMICS ON PILOT RESPONSE.
NASA CONTRACTOR REPORT CR-132459, OCTOBER 1974.

* ABSTRACT *

THIS REPORT PRESENTS THE RESULTS OF AN EXPERIMENTAL STUDY OF THE EFFECTS OF VISUAL DISPLAY DYNAMICS ON THE ALTITUDE TRACKING PERFORMANCE OF A SUBJECT IN A FIXED-BASE FLIGHT SIMULATOR. THE SUBJECT, FLYING THE LINEARIZED LONGITUDINAL EQUATIONS OF MOTION, ATTEMPTED TO MAINTAIN THE SAME ALTITUDE AS TWO AIRPLANES POSITIONED THREE HUNDRED FEET AHEAD, AS IN LEVEL FORMATION FLYING. THE HORIZON TOGETHER WITH THE TWO LEADING AIRCRAFT WERE REPRESENTED SYMBOLICALLY ON A CRT DISPLAY. THE SUBJECT'S AIRCRAFT WAS DISTURBED BY ATMOSPHERIC TURBULENCE. VARIOUS BANDWIDTHS OF SECOND-ORDER DYNAMICS WERE INTERPOSED BETWEEN THE TRUE AIRCRAFT ALTITUDE AND THE DISPLAYED ALTITUDE; NO DYNAMICS WERE INTERPOSED IN THE ALTITUDE DISPLAY. EXPERIMENTS WERE RUN USING TWO EXPERIENCED PILOTS AND TWO SUBSTANTIALLY DIFFERENT LONGITUDINAL DYNAMICS FOR THE PILOTED AIRCRAFT.

THE DATA INDICATE A RELATIONSHIP BETWEEN THE BANDWIDTH OF THE DISPLAY DYNAMICS AND THE SHORT-PERIOD CHARACTERISTICS OF THE SIMULATED AIRPLANE. FOR AN AIRPLANE WITH A RELATIVELY FAST PITCH RESPONSE (SHORT-PERIOD NATURAL FREQUENCY OF 4.8 RAD/SEC AND DAMPING RATIO OF 0.38) THE PRESENCE OF ALTITUDE DISPLAY DYNAMICS WITH A BANDWIDTH AS HIGH AS FIVE TIMES THE SHORT-PERIOD NATURAL FREQUENCY CAUSED SIGNIFICANT DEGRADATION OF ALTITUDE TRACKING PERFORMANCE. HOWEVER, FOR AN AIRCRAFT WITH SLOWER PITCH RESPONSE (SHORT-PERIOD FREQUENCY OF 2.6 RAD/SEC AND DAMPING RATIO OF 0.54) THE PRESENCE OF THE DISPLAY DYNAMICS HAD NO SIGNIFICANT EFFECT UNTIL THE BANDWIDTH WAS APPROXIMATELY TWICE THE SHORT-PERIOD NATURAL FREQUENCY.

WEMPE, T.E. 'EFFECTS OF GUST-INDUCED AND MANEUVERING ACCELERATION STRESS ON PILOT-VEHICLE PERFORMANCE'. AEROSPACE MEDICINE, MARCH 1965. VOL. 36: 246-255.

* ABSTRACT *

THREE PILOTS PERFORMING TERRAIN-CLEARANCE TASK IN CABIN WITH SIMULATED HEAVE ACCELERATIONS. CONCLUSION (BUT NOT A COMPLETE DEMONSTRATION) THAT COCKPIT MOTION HAS LARGEST EFFECT DURING PRACTICE, WHEN IT ELIMINATES ANY TENDENCY TO OVER-CONTROL.

WENDT, G.R. VESTIBULAR FUNCTIONS. IN S.S. STEVENS (ED.) 'HAND-BOOK OF EXPERIMENTAL PSYCHOLOGY'. WILEY: NEW YORK, 1951.

* ABSTRACT *

THIS CHAPTER IS A REVIEW OF THE VESTIBULE: THAT PART OF THE EAR THAT RESPONDS TO MOTION AND POSITION. THE FOLLOWING TOPICS ARE COVERED:

1. ANATOMY OF THE VESTIBULAR APPARATUS.
2. ACTION OF THE SEMICULAR CANALS AND OTOLITH ORGANS.
3. VESTIBULAR CONTROL OF THE EYES, NECK MUSCLES, TRUNK, LIMBS, AND OTHER SYSTEMS.
4. MOTION SICKNESS.
5. PERCEPTION OF MOVEMENT AND POSITION VIA THE VESTIBULE.
6. DAMAGE TO THE VESTIBULE.
7. MODIFIABILITY OF THE VESTIBULAR SYSTEMS.

WENDT, H.W. OPERATOR THRESHOLD VALUES RELEVANT FOR THE DESIGN OF MOVING BASE SIMULATORS. 'LINK ENGINEERING REPORT' ER-763, 7 MAR 1966.

* ABSTRACT *

THIS PAPER CONTAINS SELECTED EXCERPTS FROM 27 PUBLICATIONS IN THE RESEARCH LITERATURE. IT WAS DIVIDED INTO THE FOLLOWING TOPICS:

1. ANGULAR MOTION WITH VISUAL CUES PRESENT.
2. RELATIVE DIFFERENTIAL SENSITIVITY FOR MOTION AROUND PERIPHERAL AXES.
3. LINEAR ACCELERATION THRESHOLDS.
4. NATURAL, OR EVERYDAY LINEAR ACCELERATION LEVELS.
5. DIFFERENTIAL THRESHOLDS FOR LINEAR ACCELERATION.
6. DISCRIMINATING THE DIRECTION OF ACCELERATIVE FORCES.
7. ESTIMATING LATERAL DISPLACEMENT WITH THE BODY UNDERGOING LINEAR ACCELERATIONS.
8. ESTIMATES OF PITCH ANGLE.
9. TRUE PITCH AROUND AN AXIS BEHIND THE PILOT VS. VERTICAL TRANSLATION AS OPTIONS FOR SIMULATION.
10. COMPARATIVE DATA ON THRESHOLDS FOR ROTATION.
11. ACCURACY OF ESTIMATES OF SUBJECTIVE VELOCITIES DURING LOW LEVEL ANGULAR ACCELERATION.
12. ANGULAR ACCELERATION THRESHOLDS.

13. DURATION OF APPLIED ACCELERATIVE FORCES AND DURATION OF AFTER EFFECT.
14. DEFINITION OF 'SUBLIMINAL ACCELERATION' (ANGULAR) IN LABORATORY SETTINGS.
15. SELECTED SPECIFIC COMMENTS ON MOTION REQUIREMENTS IN THE SIMULATION LITERATURE.

WENDT, H.W. OPERATION MOTION THRESHOLDS AND MOVING BASE SIMULATORS: COMMENTS ON H.F. HUDDLESTON, COCKPIT MOTION REQUIREMENTS FOR FLIGHT SIMULATION. R363 (IAM, BRITISH MIMEOGRAPHED PAPER), 19 PP. 'LINK ENGINEERING REPORT' ER-839, 1 MAY 1967.

* ABSTRACT *

THIS PAPER IS A REVIEW OF HUDDLESTON'S PAPER WHICH CONTAINS SOME 50 REFERENCES, THE MAJORITY FROM THE EARLY 60'S, SOME DATING BACK TO EARLY 1930 WORK. THE AUTHOR STATES THAT HUDDLESTON'S REFERENCES OVERLAP WITH LINK'S REVIEW OF THRESHOLD WORK IN THIS AREA. (LINK ENGINEERING REPORT ER763, WENDT AND COHEN, 1966). HE ALSO POINTS OUT SOME SPECIFIC INCONSISTENCIES WITHIN THE DATA HUDDLESTON QUOTES. THE LABORATORY STUDIES ARE CONTRASTED WITH THE OPERATIONAL SETTING. THE DIFFERENCE IN SETTING, COMBINED WITH THE MUCH HIGHER OPERATIONAL TASK LOAD, WILL RAISE THE EFFECTIVE THRESHOLDS BY A SUBSTANTIAL AMOUNT. THEY WOULD BE RAISED BY MORE THAN A FACTOR OF TWO AND QUITE POSSIBLY, BY A FACTOR OF 10 OR 50. TO WORK WITH HUDDLESTON'S COMPILATION, IT MIGHT BE PRACTICAL TO USE THE MAXIMUM VALUES.

WENDT, H.W., STARK, E.A., SIMON, G.B. AND COHEN, E. THE VALUE OF COCKPIT MOTION IN FLIGHT SIMULATION: AN EXPERIMENTAL APPROACH. PAPER READ AT 'AMERICAN PSYCHOLOGICAL ASSOCIATION', SECTION ENGINEERING PSYCHOLOGY I, NEW YORK CITY, 1961.

* ABSTRACT *

USED A MOTION SYSTEM (ME-1) WHERE LATERAL TRANSLATION IS NOT ACHIEVED, YET LANDING PERFORMANCE OF TRAINED PILOT SUBJECTS WAS SIGNIFICANTLY DIFFERENT UNDER MOTION AND NON-MOTION CONDITIONS. A SYNTHETIC VISUAL DYNAMIC DISPLAY WAS AVAILABLE ALONG WITH THE LIMITED MOTION CUES.

WENDT, H.W., STARK, E.A. AND SIMON, G.B. THE EFFECT OF COCKPIT MOTION ON NIGHT LANDING PERFORMED WITH THE LINK ME-1 TRAINER AND A SYNTHETIC ELECTRONIC RUNWAY DISPLAY. 'LINK DIVISION, HUMAN FACTORS DEPARTMENT'. JAN 1961.

* ABSTRACT *

IN AN ATTEMPT TO INVESTIGATE EFFECTS OF COCKPIT MOTION IN SIMULATORS, AN EXPERIMENT WAS CONDUCTED USING THE LINK ME-1 JET TRAINER IN CONJUNCTION WITH A SYNTHETIC CONTINUOUSLY COMPUTED DISPLAY OF AN AIRPORT APPROACH AND RUNWAY LIGHT CONFIGURATION. SIX SUBJECTS WITH FLYING EXPERIENCE WERE USED; THEY WERE INSTRUCTED TO FLY AN ILS APPROACH AND TO VISUALLY MAINTAIN PROPER GLIDE SLOPE AFTER BREAKOUT, SIMULATED AT APPROXIMATELY 2 MILES BEFORE TOUCHDOWN. ALL APPROACHES WERE FLOWN WITH A SIMULATED SIDE FORCE (WIND) PRESENT, THUS CAUSING THE AIRCRAFT TO DRIFT TO THE RIGHT UNLESS CONTINUOUSLY COMPENSATED BY APPROPRIATE CONTROL INPUTS. EACH SUBJECT FLEW A NUMBER OF PRACTICE TRIALS TO A CRITERION OF TWO CONSECUTIVE LANDINGS ON THE RUNWAY, THEN EXPERIMENTAL DATA WERE OBTAINED FOR EIGHT APPROACHES WITHOUT COCKPIT MOTION AND EIGHT APPROACHES WITH MOTION, THE SEQUENCES BEING SUITABLY ALTERNATED. A TWO-CHANNEL SANBORN SYSTEM RECORDED PERFORMANCE IN TERMS OF DEVIATION FROM RUNWAY CENTERLINE AND GLIDE SLOPE, TOUCHDOWN POSITION AND CONTROL REVERSALS.

THE MAIN FINDINGS WERE AS FOLLOWS: WITHOUT MOTION, A CERTAIN MEASURE OF DRIFT WAS FOUND DUE TO THE SIDE FORCE. UNDER MOTION, THE DRIFT BECAME MORE PRONOUNCED DURING THE FINAL 40 SECONDS PRIOR TO TOUCHDOWN. AT THE SAME TIME, THE GLIDE SLOPE PERFORMANCE CHANGED TO A SLIGHTLY MORE GRADUAL TOUCHDOWN THAN WAS SEEN WITHOUT MOTION, INDICATING THAT THE PILOT WAS PAYING INCREASED ATTENTION TO THE VERTICAL DIMENSION CRITICAL FOR LANDING. THE CHANGE OVER THE NO-MOTION CONDITION WAS NOT STATISTICALLY SIGNIFICANT TAKEN BY ITSELF. HOWEVER, A NEGATIVE CORRELATION WAS FOUND BETWEEN THE MAGNITUDE OF SUCH GLIDE SLOPE CHANGES AND THE HEADING DEVIATIONS. THE MORE THE AVERAGE PILOT SUBJECT ADJUSTED HIS GLIDE SLOPE PERFORMANCE IN THE DIRECTION OF MORE GRADUAL LETDOWN, THE LESS HE COMPENSATED FOR THE WIND EFFECT, RESULTING IN A CORRESPONDINGLY LARGER DEVIATION FROM THE CENTERLINE. THIS EFFECT WAS PRONOUNCED FOR FIVE OUT OF SIX SUBJECTS WITH A CORRELATION OF -0.74 . BECAUSE OF CONSIDERABLE PRIOR EXPERIENCE ON THE ME-1 SIMULATOR WITH THE SIDE FORCE CONDITION, THE SIXTH SUBJECT DID NOT SHOW THE INTERACTION BETWEEN THE VERTICAL AND HORIZONTAL COMPONENTS OF PERFORMANCE IN THIS STUDY ALTHOUGH ASSIMILAR EFFECT HAD BEEN NOTED AT THE BEGINNING OF HIS PRACTICING PERIODS. THE CORRELATION BETWEEN GLIDE SLOPE CHANGE AND HEADING DEVIATION IS -0.39 AND THE EXPERIENCED SUBJECT IS INCLUDED.

NOT ENOUGH INSTANCES OF CONTROL REVERSALS WERE RECORDED TO PERMIT CHECKING THE POSSIBLE EFFECTS OF MOTION ON THIS VARIABLE.

THE RESULTS WERE TAKEN AS EVIDENCE FOR THE MODEL OF A CONSTANT CHANNEL CAPACITY OF THE OPERATOR INPUTS. APPARENTLY THE SIMULATOR MOTION ACTS AS A STRESS CONDITION WHICH, THROUGH THE MORE REALISTIC CUES PROVIDED, WILL CAUSE THE PILOT TO IMPROVE HIS LETDOWN, AT THE SYSTEMATIC EXPENSE OF SIMULTANEOUS HEADING PERFORMANCE OR, POSSIBLE, OTHER SUB-TASKS.

EVIDENCE FROM OTHER STUDIES IS BRIEFLY DISCUSSED. THE GENERAL CONSENSUS APPEARS TO BE THAT MOTION IS AT LEAST DESIRABLE IN A FLIGHT SIMULATOR AND IS MANDATORY FOR MANY TRAINING TASKS FOR WHICH SIMULATORS ARE USED. FROM DATA OF OTHER STUDIES, AS WELL AS THIS STUDY, IT APPEARS THAT THE TRAINING VALUE OF MOTION IS APPRECIABLE, IN THE SENSE OF CREATING MORE REALISTIC (AND TO SOME EXTENT, MORE DIFFICULT) CONDITIONS. THERE WAS NO OPPORTUNITY TO TEST TRANSFER EFFECTS FOR THE AIRBORNE PHASES OF FLIGHT TRAINING.

OUR RECOMMENDATION WOULD BE THAT EMPHASIS BE PLACED ON MOTION IN CONNECTION, ESPECIALLY WITH THE NON-ROUTINE ASPECTS OF TRAINING WHICH ALSO CONTRIBUTE MOST HEAVILY TO OVER-ALL SAFETY.

WESTBROOK, C.B. SIMULATION IN MODERN AERO-SPACE VEHICLE DESIGN. NORTH ATLANTIC TREATY ORGANIZATION. 'ADVISORY GROUP FOR AERO-NAUTICAL RESEARCH AND DEVELOPMENT' (AGARD) REPORT 366, APRIL, 1961.

* ABSTRACT *

IN THE DESIGN OF MODERN AERO-SPACE VEHICLES THE USE OF SIMULATORS HAS BECOME MORE AND MORE WIDESPREAD. IN THIS PAPER, A REVIEW IS MADE OF THE SIMULATION FACILITIES COMMONLY USED IN THE AIRCRAFT RESEARCH AND DEVELOPMENT PROCESS IN THE UNITED STATES. AN ATTEMPT IS MADE TO CLASSIFY THESE FACILITIES AND TO UNDERSTAND HOW AND WHY THEY ARE NEEDED AND CAME INTO BEING, AND HOW THEY ARE USED. IT IS HOPED THAT THIS COLLECTION OF INFORMATION, THE CODIFICATIONS AND CONCLUSIONS MAY BE OF SOME BENEFIT TO THOSE WHO USE AND ARE PLANNING TO USE SIMULATION FACILITIES.

BEFORE PROCEEDING FURTHER, IT IS NECESSARY TO CLARIFY WHAT IS MEANT BY THE WORD SIMULATOR. AS COMMONLY USED BY VARIOUS INDIVIDUALS OF DIFFERING INTERESTS, IT HAS A RATHER WIDELY VARYING DEFINITION. FOR THE PURPOSE OF THIS REPORT, SIMULATORS ARE INITIALLY CONSIDERED, IN THE BROADEST SENSE, AS FACILITIES WHICH WILL ALLOW AN ANALOG REPRESENTATION OF A PARTICULAR CONTROL ELEMENT, COMBINATION OF CONTROL ELEMENTS OR THE COMPLETE FLIGHT CONTROL AIRFRAME PILOT SYSTEM. THIS WOULD INCLUDE SIMULATORS TO OBTAIN DATA ON CONTROL HARDWARE, THE HUMAN PILOT AND HIS DISPLAY, THE AIRFRAME WITH ELASTICITY, AND THE COMPLETE SYSTEM. CLASSIFICATION OF SIMULATORS IN VARIOUS WAYS IS PERFORMED AND EXISTING FACILITIES DESCRIBED. CONSIDERATION OF THE WIDE SPECTRUM OF SIMULATORS UNDER THIS BROAD DEFINITION IS USEFUL IN GIVING A PERSPECTIVE VIEW OF THE SUBJECT.

ATTENTION IS THEN PARTICULARLY DIRECTED AT SIMULATORS USED IN THE VARIOUS PHASES OF DEVELOPMENT OF A TYPICAL VEHICLE. THESE PHASES INCLUDE THE PRELIMINARY DESIGN PHASE, THE DETAILED DESIGN AND DEVELOPMENT PHASE, AND THE EXPERIMENTAL FLIGHT TEST PHASE.

FINALLY SOME THOUGHTS ON THE PHILOSOPHY OF USE OF SIMULATORS
ARE GIVEN AND A SUMMARY AND CONCLUSIONS PRESENTED.

WESTBROOK, C.B. BACKGROUND OF PILOTED SIMULATOR DEVELOPMENT
AIR FORCE FLIGHT DYNAMICS LABORATORY, RESEARCH AND TECHNOLOGY
DIVISION, REPORT FDCC TM 64-28, AUG. 1964.

* ABSTRACT *
IN THIS PAPER A REVIEW IS MADE OF THE PILOTED SIMULATION
FACILITIES COMMONLY USED IN THE UNITED STATES. AN ATTEMPT IS
MADE TO CLASSIFY THESE FACILITIES AND TO UNDERSTAND HOW AND
WHY THESE FACILITIES ARE NEEDED AND CAME INTO BEING AND HOW
THEY ARE USED. SOME THOUGHTS ON THE PHILOSOPHY OF USE OF
SIMULATION ARE OFFERED AND CONCLUSIONS PRESENTED.

J.C. WHITE - SERV0 ASSIST BUNGE
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NO ABSTRACT

WHITE, M.D., BRAY, R.S. AND COOPER, G.E. PAPER CITED IN SADOFF,
M., AND HARPER, C.W. 'AEROSPACE ENGINEERING, 1962.

* ABSTRACT *
STUDIES ON SUPERSONIC TRANSPORT STABILITY AND HANDLING DURING
CRUISE. DATA FROM AMES 3DF (PITCH, ROLL, YAW) AND AMES 5DF
(PITCH, ROLL, YAW, HEAVE, SWAY) COMPARED TO VARIABLE STABILITY
AIRCRAFT FLIGHT. GENERALLY GOOD AGREEMENT. 5DF EXPERIENCE GAVE
RISE TO POORER PILOT RATINGS OF AIRCRAFT THAN 3DF, PROBABLY
MOSTLY DUE TO SWAY MOTIONS, AND MADE PILOTS MORE CONFIDENT IN
RATING CERTAIN CONTROL SITUATIONS.

WHITE, M.D. AND COOPER, G.E. A PILOTED SIMULATION STUDY OF OP-
ERATIONAL ASPECTS OF THE STALL PITCH-UP. AMES RESEARCH CENTER,
NASA TECHNICAL NOTE D-4071, JULY 1967.

* ABSTRACT *
A PILOTED SIMULATOR STUDY WAS CONDUCTED TO INVESTIGATE THE
STALLING CHARACTERISTICS OF TRANSPORT-TYPE AIRPLANES WITH
LOCALIZED INSTABILITIES ASSOCIATED WITH THE PITCHING MOMENT

VARIATIONS AT THE STALL. PITCHING-MOMENT VARIATIONS OF THIS GENERAL CLASS WERE FOUND TO BE CONDUCTIVE TO THE DEVELOPMENT OF SERIOUS STALLS WHETHER THE UNSTABLE 'BUMP' IN THE PITCHING-MOMENT VARIATION WAS LARGE OR SMALL, THE IMPORTANT FACTORS BEING, RESPECTIVELY, INABILITY TO CHECK THE MOTION, AND LACK OF INDICATION OF THE STALL PENETRATION. THE STABILITY LEVEL AT ANGLES OF ATTACK ABOVE THE UNSTABLE BUMP WAS OF PRIMARY IMPORTANCE IN DEFINING THE DEPTH OF STALL PENETRATION. FACTORS THAT HAD PREVIOUSLY BEEN IDENTIFIED AS SIGNIFICANT TO THE PROBLEM OF CONTROLLING THE DEEP STALL OF T-TAIL AIRPLANES (I.E., THE INADEQUACY OF ATTITUDE INFORMATION AND THE IMPORTANCE OF PROMPT AND SUSTAINED RECOVERY CONTROL APPLICATION) WERE ALSO CONSIDERED SIGNIFICANT FOR THE PITCHING-MOMENT CHARACTERISTICS INVESTIGATED HERE. (AUTHOR)

 WHITE, M.D., VOMASKE, R.F., MCNEILL, W.E., AND COOPER, G.E. A PRELIMINARY STUDY OF HANDLING-QUALITIES REQUIREMENTS OF SUPERSONIC TRANSPORTS IN HIGH-SPEED CRUISING FLIGHT USING PILOTTED SIMULATORS. NATIONAL AERONAUTICS AND SPACE ADMINISTRATION TECHNICAL NOTE D-1888, AMES RESEARCH CENTER, MOFFETT FIELD, CA, MAY 1963.

* ABSTRACT *

TWO DIFFERENT SIMULATORS WERE USED IN A PILOTTED MOTION SIMULATOR STUDY TO OBTAIN PRELIMINARY HANDLING-QUALITIES DATA ON A SUPERSONIC TRANSPORT IN CRUISING FLIGHT AT MACH NUMBER OF 3.0.

RESULTS INDICATE THAT FOR CONFIGURATIONS CURRENTLY BEING CONSIDERED FOR THE SUPERSONIC TRANSPORT, AUGMENTATION OF THE ROTATIONAL DAMPING CHARACTERISTICS IS LIKELY TO BE REQUIRED AROUND ALL THREE AXES, THE GREATEST INCREMENT BEING REQUIRED FOR THE YAW AXIS. THE STATIC STABILITY CHARACTERISTICS, HOWEVER, APPEAR TO REQUIRE LESS AUGMENTATION THAN THE DAMPING CHARACTERISTICS. THE PROBLEM OF LIMITING THE SIDESLIP EXCURSIONS FOLLOWING A BRUTAL LOSS OF THRUST OF AN OUTBOARD PODDED ENGINE CONTRIBUTED GREATLY TO THE REQUIREMENTS FOR DIRECTIONAL DAMPING AND STABILITY. THE SATISFACTORY HANDLING-QUALITIES CHARACTERISTICS DEFINED FOR A TRANSPORT AIRPLANE BY THIS STUDY DIFFER FROM THOSE DEFINED IN PREVIOUS STUDIES OF FIGHTER-TYPE AIRPLANES, AND INDICATE A NEED FOR A SEPARATE APPRAISAL OF TRANSPORT HANDLING-QUALITIES REQUIREMENTS. ACCURATE APPRAISAL OF THE EFFECTS OF LARGE DISTURBANCES OF THE AIRPLANE REQUIRES SIMULATOR CAPABILITIES THAT REPRODUCE TRANSLATIONAL AS WELL AS ROTATIONAL MOTIONS.

 WILCOXON, H.C. AND DAVY, E. FIDELITY OF SIMULATION IN OPERATIONAL FLIGHT TRAINERS, PART I: EFFECTIVENESS OF ROUGH AIR SIMULATION. NSDC TECHNICAL REPORT 999-2-3, SPECIAL DEVICES CENTER, PORT WASHINGTON, NEW YORK, AD-140 998, 24 JANUARY 1954.

* ABSTRACT *

THE PURPOSE OF THIS STUDY WAS TO INVESTIGATE THE EFFECT OF ROUGH AIR SIMULATION ON BASIC INSTRUMENT AND RADIO RANGE PROCEDURE TRAINING. THE RESULTS INDICATED THAT: (1) PERFORMANCE IN THE AIRCRAFT ON BASIC INSTRUMENT AND RADIO RANGE PROCEDURES REVEAL NO SIGNIFICANT DIFFERENCES BETWEEN GROUPS TRAINED WITH ROUGH AIR AND THOSE NOT. (2) NO DIFFERENCES WERE FOUND IN NUMBER OF FLIGHTS REQUIRED TO COMPLETE THE SYLLABUS. (3) ROUGH AIR SIMULATION DOES SEEM TO ADD REALISM TO THE TRAINER AND INCREASES STUDENT ACCEPTANCE OF IT.

ACCEPTABILITY OF A TRAINER TO STUDENTS AND TRAINING PERSONNEL SEEMS TO BE A FACTOR WHICH SHOULD BE WEIGHED IN CONSIDERING DESIGN OF FLIGHT TRAINERS. ACCEPTANCE SHOULD AND CAN BE ACHIEVED THROUGH DESIGNS WHICH CONTRIBUTE TO TRAINING. ROUGH AIR IS NOT A NECESSARY ELEMENT IN BASIC INSTRUMENT AND RADIO NAVIGATION TRAINING, AND IS THEREFORE NOT ECONOMICALLY JUSTIFIED.

ALCOXON, H.C. AND DAVY, E. FIDELITY OF SIMULATION IN OPERATIONAL FLIGHT TRAINERS. PART II. THE PSYCHOLOGICAL CORPORATION. SPECIAL DEVICES CENTER TECHNICAL REPORT SDC 993-2-3B'. PART WASHINGTON, L.I. N.Y. 1954.

* ABSTRACT *

THE MAJOR FINDING OF THIS STUDY IS THAT FOR THE PURPOSE OF TEACHING BASIC INSTRUMENT SKILL IN THE SNJ AIRCRAFT, THE CONTROL LOADINGS OF THE SNJ OBT MAY BE VARIED OVER A WIDE RANGE WITHOUT AFFECTING THE TRAINING VALUE OF THE DEVICE. FIDELITY OF PRESSURE DOES NOT SEEM TO BE AN IMPORTANT FACTOR IN THIS KIND OF TRAINING.

WHATEVER NEGATIVE HABITS WERE DEVELOPED IN THE HIGH AND LOW PRESSURE OBT'S WERE PROBABLY NOT CARRIED OVER TO THE AIRCRAFT TO AN IMPORTANT EXTENT. NO TENDENCIES FOR STUDENTS TO OVER-CONTROL OR UNDER-CONTROL THE AIRCRAFT AS A RESULT OF TRAINING IN A PARTICULAR OBT WERE OBSERVED. NO DIFFERENCES IN FLIGHT EFFICIENCY WERE OBSERVED. A POSSIBLE EXPLANATION OF THESE FACTS IS THAT ALL STUDENTS USED IN THIS STUDY HAD HAD CONSIDERABLE EXPERIENCE IN THE AIRCRAFT. THE EFFECT OF THE BRIEF PERIOD DURING WHICH SOME FLEW THE MODIFIED OBT'S WAS NOT GREAT ENOUGH TO ALTER THEIR BASIC FLYING SKILLS. THERE IS EVIDENCE THAT A LOW PRESSURE LOADING MAKES THE TRAINER MORE DIFFICULT FOR THE STUDENT TO FLY, BUT APPARENTLY HE ADAPTS TO THIS AND SOON BECOMES NORMALLY PROFICIENT IN THE DEVICE.

MILKERSON, L., NORMAN, D., MATHENY, W., DEMAREE, R. AND LOWES, A. PILOT PERFORMANCE, TRANSFER OF TRAINING AND DEGREE OF SIMULATION: VARIATIONS IN PROGRAM CYCLE TIME AND AERODYNAMIC EQUIVA-

TRANS: NAVTRADEVCEEN 1388-2. U.S. NAVAL TRAINING DEVICE CENTER, PORT WASHINGTON, NEW YORK, DECEMBER 1965.

* ABSTRACT *

THIS REPORT, THE SECOND IN A PROGRAM, PRESENTS TWO EXPERIMENTS DEALING WITH PILOT PERFORMANCE, TRANSFER OF TRAINING AND DEGREE OF SIMULATION. IN THE STUDIES REPORTED HEREIN, CURRENTLY QUALIFIED JET FIGHTER PILOTS FLEW SPECIFIED MANEUVERS USING THE UNIVERSAL DIGITAL OPERATIONAL FLIGHT TRAINER TOOL (UDOFFT) UNDER VARIATIONS OF PROGRAM CYCLE TIME AND OF THE AERODYNAMIC EQUATIONS. TWO EXPERIMENTS ARE REPORTED.

EXPERIMENT ONE INVESTIGATED PILOT PERFORMANCE UNDER PROGRAM CYCLE TIMES OF 50 AND 83 MILLISECONDS AND UNDER SETS OF AERODYNAMIC EQUATIONS WHICH WERE EITHER COMPLETE OR SIMPLIFIED. ALTHOUGH A PROGRAM ERROR LED TO INCONCLUSIVE RESULTS REGARDING PROGRAM CYCLE TIMES, THE USE OF THE SIMPLIFIED SET OF EQUATIONS WAS SHOWN TO HAVE NO ADVERSE EFFECT UPON PILOTING PERFORMANCE.

EXPERIMENT TWO INVESTIGATED THE QUESTION OF WHETHER OR NOT PILOTS CAN BE TRAINED ON RESTRICTED SIMULATOR CONDITIONS AND THEN TRANSFERRED TO REALISTIC CONDITIONS WITH NO SIGNIFICANT LOSS IN PERFORMANCE. RESTRICTED CONDITIONS WERE IDENTIFIED AS HAVING AN 83 MILLISECOND PROGRAM CYCLE TIME AND A SIMPLIFIED SET OF AERODYNAMIC EQUATIONS. AN ADDITIONAL PURPOSE OF EXPERIMENT TWO WAS TO CLARIFY THE INCONCLUSIVE FINDINGS OF EXPERIMENT ONE. THE RESULTS OF THIS EXPERIMENT REVEALED THAT PILOTS COULD BE TRAINED UNDER RESTRICTED SIMULATOR CONDITIONS AND EFFECTIVELY TRANSFERRED TO REALISTIC SIMULATOR CONDITIONS WITHOUT ANY SIGNIFICANT DECREMENT IN PERFORMANCE. FURTHERMORE, IT WAS DETERMINED THAT INCREASED PROGRAM CYCLE TIME HAD NO ADVERSE EFFECT ON PILOT PERFORMANCE.

WILLIAMS, A.C. JR. AND ADELSON, M. 'SOME CONSIDERATIONS IN DECIDING ABOUT THE COMPLEXITY OF FLIGHT SIMULATORS', US AFPTC, RESEARCH BULLETIN, 56-106, DECEMBER 1964, DSIS 55/8538.

* ABSTRACT *

THIS RESEARCH BULLETIN DESCRIBES A POSSIBLE METHOD FOR DETERMINING THE DEGREE OF EXACTNESS OF SIMULATION REQUIRED OF A FLIGHT SIMULATOR. TO THIS END, CONSTRUCTION OF A VARIABLE CHARACTERISTIC SIMULATOR IS PROPOSED; THE SIMULATOR WOULD HAVE 34 PERFORMANCE CHARACTERISTICS OF THE T-33 AIRCRAFT, AND EACH CHARACTERISTIC WOULD BE CAPABLE OF VARIATION OVER AN AVERAGE RANGE OF FIVE STEPS. BY MEANS OF CONTROLLED ADJUSTMENTS IN THE SIMULATOR, DIFFERING CONDITIONS OF EXACTNESS OF SIMULATION WOULD BE OBTAINED. TRANSFER OF TRAINING EXPERIMENTS COULD THEN BE EXECUTED UNDER THESE VARIOUS CONDITIONS WHICH WOULD PERMIT COMPARISON OF PERFORMANCE OF STUDENTS TRAINED IN THE SIMULATOR AND THEN IN THE T-33 WITH PERFORMANCE OF STUDENTS TRAINED ONLY

IN THE T-33. SPECIFICATIONS FOR THE PROPOSED SIMULATOR ARE APPENDED.

WILLIGES, BEVERLY H., STANLEY N. ROSCOE, AND ROBERT C. WILLIGES.
SYNTHETIC FLIGHT TRAINING REVISITED
HUMAN FACTORS, 1973, 15(5), 543-560

* ABSTRACT *

CRITICAL ISSUES IN THE DEVELOPMENT AND USE OF SYNTHETIC FLIGHT TRAINERS ARE REVIEWED. DEGREE OF SIMULATION AND FIDELITY OF SIMULATION ARE DISCUSSED AS KEY DESIGN CONSIDERATIONS. PROBLEMS IN MEASUREMENT OF ORIGINAL LEARNING, TRANSFER, AND RETENTION ARE PRESENTED. BOTH TRANSFER EFFECTIVENESS AND COST EFFECTIVENESS ARE DESCRIBED AS CRITICAL FACTORS IN THE EVALUATION OF FLIGHT TRAINERS. RECENT TRAINING INNOVATIONS, SUCH AS AUTOMATICALLY ADAPTIVE TRAINING, COMPUTER-ASSISTED INSTRUCTION, CROSS-ADAPTIVE MEASUREMENT OF RESIDUAL ATTENTION, COMPUTER GRAPHICS, INCREMENTAL TRANSFER EFFECTIVENESS MEASUREMENT, AND RESPONSE SURFACE METHODOLOGY, ARE DISCUSSED AS POTENTIAL TECHNIQUES FOR IMPROVING SYNTHETIC FLIGHT TRAINING. IT IS CONCLUDED THAT BROADER APPLICATION OF SIMULATION IS NECESSARY TO MEET THE NEW DEMANDS OF PILOT TRAINING, CERTIFICATION, AND CURRENCY ASSURANCE IN AIR TRANSPORTATION.

WILLIGES, R.C., HOPKINS, C.E. AND ROSE, D.J. EFFECTS OF AIRCRAFT SIMULATOR MOTION CUE FIDELITY ON PILOT PERFORMANCE.
DEUTSCHE GESELLSCHAFT FÜR ORTUNG UND NAVIGATION, NATIONALE TAGUNG ÜBER SIMULATION IM DIENSTE DES VERKEHRS, BREMAN, W. GERMANY. PAPER 1.2, APRIL 1975. (IN GERMAN).

* ABSTRACT *

THE PURPOSE WAS TO FIND WHETHER AND HOW SIMULATOR MOTION CUE FIDELITY VARIES WITH THE DESIRED APPLICATION OF A SIMULATOR. WHEN THE SIMULATOR WAS USED FOR EQUIPMENT DESIGN RESEARCH, IT WAS FOUND THAT HIGH FIDELITY WASHOUT MOTION (WHERE RATE OF ROLL RATHER THAN BANK ANGLE IS THE INPUT) PRODUCED RESULTS MOST AKIN TO FLIGHT. WHEN THE SIMULATOR WAS USED FOR PILOT PROFICIENCY ASSESSMENT, LESS REALISTIC SUSTAINED MOTION (WITH THE COCKPIT FOLLOWING A SCALED-DOWN LINEAR ANALOGUE OF BANK ANGLE AFTER A CERTAIN TIME LAG) PROVIDED PILOT PERFORMANCE DATA OF THE HIGHEST PREDICTIVE VALUE. WHEN THE SIMULATOR WAS USED AS A TRAINING DEVICE FOR INFERENCE-REFERENCED MANEUVERS, THE NO-MOTION CONDITION YIELDED AS MUCH TRANSFER AS EITHER OF THE OTHER SIMULATOR MOTION MODELS.

WILLIGES, R.C. AND ROSCOE, S.N. SIMULATOR MOTION IN AVIATION SYSTEM DESIGN RESEARCH. 'AVIATION RESEARCH LABORATORY', INSTITUTE OF AVIATION, UNIVERSITY OF ILLINOIS, URBANA, ILLINOIS TECHNICAL REPORT ARL-73-6/ONR-73-2/AFOSR-73-3, MAY 1973. PAPER PRESENTED AT NATO SEMINAR ON MAN MACHINE RELATIONS, UTRECHT, THE NETHERLANDS, 28-30 MAY 1973.

* ABSTRACT *

IN THREE STUDIES, THE ORDER OF MERIT OF FOUR FLIGHT-DIRECTOR, ATTITUDE-INDICATOR DISPLAYS (MOVING HORIZON, MOVING AIRPLANE, FREQUENCY-SEPARATED, AND KINALOG) WAS ASSESSED UNDER THREE CONDITIONS OF SIMULATOR MOTION (NO MOTION, NORMAL GAT-2 SIMULATOR MOTION, AND WASHOUT MOTION), AND THE RESULTS WERE COMPARED TO FLIGHT PERFORMANCE. COMPARISONS AMONG THE STUDIES WERE MADE TO DETERMINE WHETHER OR NOT PERFORMANCE ON VARIOUS DISPLAY MODES WAS DIFFERENTIALLY AFFECTED BY SIMULATOR MOTION CUES, AND IF SO, WHAT DEGREES AND FIDELITY OF SIMULATOR MOTION WERE REQUIRED TO PRODUCE RESULTS THAT GENERALIZED TO FLIGHT PERFORMANCE. IT WAS CONCLUDED THAT THE PRESENCE OR ABSENCE OF MOTION CANNOT ONLY AFFECT ABSOLUTE LEVELS OF PERFORMANCE, BUT DIFFERENT ORDERS OF MERIT AMONG DISPLAYS CAN OCCUR. SPECIFICALLY, INAPPROPRIATE COCKPIT MOTION MAY BE MORE MISLEADING THAN NO MOTION, WHEREAS LIMITED MOTION IN PITCH AND ROLL THAT CORRESPONDS CLOSELY TO THE ANGULAR ACCELERATIONS ENCOUNTERED IN FLIGHT MAY BE SUFFICIENT TO PRODUCE GENERALIZABLE RESEARCH DATA ON THE RELATIVE MERITS OF FLIGHT DISPLAYS. THE EFFECT OF MOTION CUES ON PILOT PERFORMANCE IS COMPLEX, AND POTENTIAL INTERACTIONS AMONG VISUAL MOTION CUES, PILOT WORKLOAD, PILOT EXPERIENCE, AND THE DEGREES AND FIDELITY OF MOTION SIMULATION NEED FURTHER INVESTIGATION.

WILLIS, J.M.
BELL HELICOPTER CORPORATION.
RESULTS OF ENGINEERING TEST MADE ON THE FRANKLIN INSTITUTE
DYNAMIC FLIGHT SIMULATOR.
FORT WORTH, TEXAS
REPORT NO. D228-37C-001, APRIL 1960, 48 PP. AD236 660

* ABSTRACT *

THE PURPOSE OF THESE TESTS WAS TO DETERMINE VELOCITY LIMITS, ACCELERATION LIMITS, MAGNITUDE AND FREQUENCY OF UNWANTED SIGNALS. PARTICULAR ATTENTION WAS GIVEN TO THE LOWER FREQUENCY LARGE EXCURSION SIGNALS PRESENTED TO THE PLATFORM BY THE COMPUTER DURING THE SIMULATED FLIGHT. IT IS FELT THAT SIGNALS SUCH AS THESE ARE MORE REPRESENTATIVE OF THE ACTUAL MOTION OF THE HELICOPTER. CONCLUSIONS WERE THAT THE EXISTING DISTANCE AVAILABLE FOR ACCELERATION IS VERY NEAR OPTIMUM IN MOST CHANNELS. MOST OF THE NOISE NOTED HAD A DEFINITE FREQUENCY COMPONENT OF 2 CPS., THE PLATFORM NATURAL FREQUENCY IN MOST CHANNELS. IN MOST CASES LARGER SERVO VALVES WILL IMPROVE

MAXIMUM VELOCITIES AND ACCELERATIONS OBTAINABLE, AS THE LARGEST PERCENTAGE OF THE HYDRAULIC PRESSURE DROP IS PRODUCED BY THE SERVO VALVE, WITH VERY LITTLE PRESSURE REMAINING TO ACCELERATE THE LOAD. MANY MODIFICATIONS WERE MADE TO IMPROVE THE PERFORMANCE OF THE PLATFORM DURING THE TEST. THE RESULTS SHOWN IN THIS REPORT REPRESENT THE OPTIMUM OBTAINED FROM THESE MODIFICATIONS.

WILSON, D. ADVANCES IN MOTION PLATFORM SYSTEMS. IN PROCEEDINGS TWO-DAY SYMPOSIUM ON FLIGHT TRAINING SIMULATORS FOR THE 70'S. 14/15 OCTOBER 1970, THE ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 0BQ

* ABSTRACT *
DISCUSSES THE HISTORY OF MOTION SIMULATION AT LINK WITH THE CONCLUSION THAT THE FLIGHT SIMULATOR INDUSTRY IS CAPABLE OF DESIGNING AND PRODUCING RELIABLE MULTIFREEDOM MOTION SYSTEMS WHICH FULFIL THE CURRENT TECHNICAL AND OPERATIONAL REQUIREMENTS. HOWEVER, IT IS POINTED OUT THAT TOO LITTLE IS KNOWN ABOUT THE REAL WORLD RELATIONSHIP BETWEEN MOTION CUES, PILOT REACTION AND INSTRUMENT RESPONSES, PARTICULARLY IN THE REGIME OF SMALL MAGNITUDE PERTURBATIONS FROM STEADY STATE FLIGHT CONDITIONS.

IN ADDITION, IF FURTHER ADVANCES ARE TO BE MADE IN MOTION SYSTEM EFFECTIVENESS, INDUSTRY REQUIRES MUCH MORE DATA RELATING TO THE PHYSIOLOGICAL AND PSYCHOLOGICAL ASPECTS OF PILOT RESPONSE TO AIRCRAFT MOTION.

WITKIN, H.A. PERCEPTION OF BODY POSITION AND OF THE POSITION OF THE VISUAL FIELD. PSYCHOLOGICAL MONOGRAM, NO. 302, 1949.

* ABSTRACT *
IN ORDER TO PERMIT AN INVESTIGATION OF THE FACTORS INVOLVED IN PERCEPTION OF THE POSITION OF THE BODY AND OF THE FIELD AS A WHOLE, AND IN ORDER TO INVESTIGATE ORIENTATION UNDER MORE NATURAL CONDITIONS THAN THOSE USED IN PREVIOUS STUDIES OF THIS SERIES, A NEW KIND OF APPARATUS WAS DEVELOPED FOR THIS STUDY. THIS APPARATUS CONSISTED OF A SMALL ROOM WHICH COULD BE TILTED TO LEFT AND RIGHT, WITHIN WHICH WAS A CHAIR WHICH COULD ALSO BE TILTED TO LEFT AND RIGHT. USING THIS APPARATUS IT WAS ESTABLISHED, FIRST OF ALL, FOR A GROUP OF 45 SS, THAT WITH MOVEMENT OF THE ROOM THERE WAS INDUCED IN MOST PEOPLE, A STRONG ILLUSION OF BODY MOVEMENT. IN ANOTHER SYSTEMATIC SERIES OF TESTS CARRIED OUT ON A GROUP OF 54 SS, THE ROOM AND BODY WERE INITIALLY TILTED, AND THE S WAS REQUIRED TO BRING THE ONE OR THE OTHER TO THE UPRIGHT POSITION. IN STRAIGHTENING THE ROOM, THERE WAS A GENERAL TENDENCY TO UNDERESTIMATE ITS TILT, SO THAT IT WAS OFTEN PERCEIVED AS UPRIGHT EVEN IN VERY TILTED POSITIONS.

THERE WERE IMPORTANT INDIVIDUAL DIFFERENCES IN THIS REGARD, HOWEVER, WITH SOME SS TENDING TO PERCEIVE THE ROOM AS STRAIGHT EVEN AT ITS INITIAL TILT, AND OTHERS AT THE OPPOSITE EXTREME, PROVING ABLE TO BRING THE ROOM TO WITHIN A FEW DEGREES OF THE UPRIGHT POSITION. IN STRAIGHTENING THE BODY, IT WAS FOUND THAT THE ADJUSTMENT WAS BASED NOT ONLY ON POSTURAL EXPERIENCES (ELIMINATING PRESSURES AGAINST THE SIDE) BUT ALSO ON VISUAL IMPRESSIONS (HAVING THE BODY APPEAR STRAIGHT IN RELATION TO THE SURROUNDING FIELD). IN FACT, IT WAS ESTABLISHED IN A STUDY USING 46 SS THAT IN SOME CASES, PRESSURES OF FAIRLY LARGE MAGNITUDE WENT UNDETECTED AS A RESULT OF THE VISUAL IMPRESSION THAT THE BODY WAS UPRIGHT. IMPORTANT INDIVIDUAL DIFFERENCES WERE AGAIN FOUND IN THE PERCEPTION OF BODY POSITION. WHERE SOME SS WERE ABLE TO BRING THE BODY VERY CLOSE TO THE UPRIGHT POSITION, REGARDLESS OF THE TILT OF THE SURROUNDING ROOM, OTHERS TENDED TO BRING THE BODY INTO ALIGNMENT WITH THE TILTED FIELD IN MAKING IT STRAIGHT. CORRELATIONS OF THE SCORES OBTAINED UNDER THE VARIOUS EXPERIMENTAL CONDITIONS USED INDICATE THAT THERE IS SOME CONSISTENCY IN PERFORMANCE, MORE SPECIFICALLY, IN THE EXTENT TO WHICH PERCEPTION OF THE EXTERNAL UPRIGHT AND OF BODY POSITION ARE INFLUENCED BY THE IMMEDIATE VISUAL FIELD. IT HAS ALSO BEEN FOUND THAT SOME SS NOT ONLY MAKE LARGE ERRORS IN THEIR ESTIMATES OF THE POSITION OF THE ROOM AND BODY, BUT THEY ALSO EXPERIENCE GREAT DIFFICULTY IN MAKING JUDGMENTS. IN SOME CASES, SS EVEN BECAME ILL. EVIDENCE IS PRESENTED FROM A STUDY OF 45 SS WHICH INDICATES THAT THE ILLNESS WAS CAUSED BY A LOSS OF ORIENTATION. FINALLY, AN ANALYSIS OF SOME OF THE STUPID ERRORS MADE IN THE SOLUTION OF THESE ORIENTATION TESTS INDICATES THAT THEIR BASIS LIES NOT IN A 'LACK OF INTELLIGENCE' BUT IN AN INDIVIDUAL'S PARTICULAR MADE OF PERCEIVING THE SITUATION, OR IN THE SUPPRESSION OF CERTAIN EXPERIENCES UNDER CONDITIONS OF SENSORY CONFLICT.

WITKIN, H.A. PERCEPTION OF THE UPRIGHT WHEN THE DIRECTION OF THE FORCE ACTING UPON THE BODY IS CHANGED. JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 1950, 40, 93-106.

* ABSTRACT *

AS AN EXTENSION OF EARLIER STUDIES IN WHICH THE VISUAL BASIS FOR PERCEPTION OF THE UPRIGHT WAS ALTERED IN BASIC FASHION, THE PRESENT STUDY INVESTIGATED THE EFFECT OF A BASIC CHANGE IN THE POSTURAL DETERMINANTS OF THE PERCEIVED UPRIGHT. TO ACCOMPLISH SUCH A CHANGE IN POSTURAL FACTORS, THE SUBJECT WAS ROTATED ABOUT A CIRCULAR PATH, SO THAT THE EFFECTIVE FORCE ACTING ON HIS BODY WAS SHIFTED FROM THE TRUE UPRIGHT, AND NOW CORRESPONDED IN DIRECTION TO THE RESULTANT BETWEEN THE DOWNWARD PULL OF GRAVITY AND THE Laterally-acting CENTRIFUGAL FORCE. DURING ROTATION THE SUBJECT WAS SEATED IN A FULLY ENCLOSED ROOM, AND HIS TASK WAS TO ADJUST A ROD ON ITS FRONT WALL TO THE TRUE VERTICAL AND HORIZONTAL. TESTS WERE CONDUCTED AT TWO SPEEDS OF ROTATION AND AT EACH SPEED THE SUBJECT WAS TESTED BOTH WITH A VISUAL

FIELD AND WITHOUT A VISUAL FIELD. A TOTAL OF 258 SUBJECTS SERVED IN THE VARIOUS EXPERIMENTS REPORTED HERE.

IT WAS FOUND, FIRST OF ALL, THAT WHEN AN UPRIGHT VISUAL FIELD WAS PRESENT, A SHIFT IN THE FORCE ACTING ON THE BODY HAD A VERY SMALL EFFECT ON THE PERCEIVED UPRIGHT. AT THE LOWER SPEED OF ROTATION, WITH THE FORCE ON THE BODY SHIFTED BY 20.5 DEGREES, THE ERROR IN ADJUSTING THE ROD TO THE VERTICAL AND HORIZONTAL WAS ONLY 3.1 DEGREES (THAT IS, THE ROD WAS OFF BY THAT AMOUNT FROM THE AXES OF THE FIELD, OR FROM THE TRUE VERTICAL AND HORIZONTAL). AT THE HIGHER SPEED, WITH THE FORCE ON THE BODY SHIFTED BY 33.4 DEGREES, THE ERROR IN ADJUSTING THE ROD WAS ONLY 6.3 DEGREES. THUS, UNDER CONDITIONS OF CONFLICT BETWEEN VISUAL AND POSTURAL DETERMINANTS OF THE PERCEIVED UPRIGHT, THE FORMER PROVED MORE IMPORTANT. IN THE ABSENCE OF A VISUAL FIELD, SHIFTING THE FORCE ON THE BODY THROUGH ROTATION HAD A MUCH GREATER EFFECT ON THE PERCEIVED UPRIGHT. AT THE LOWER SPEED, THE MEAN ERROR IN ADJUSTING THE ROD ROSE TO 10.7 DEGREES, AND AT THE HIGHER SPEED TO 24.7 DEGREES. NOT ONLY DID REMOVAL OF THE FIELD LEAD TO LARGER ERRORS IN THE SETTING OF THE ROD, BUT IN MOST CASES IT ALSO CAUSED THE BODY ITSELF TO FEEL MORE TILTED.

MARKED INDIVIDUAL DIFFERENCES WERE FOUND AMONG SUBJECTS IN MANNER OF ESTABLISHING THE UPRIGHT, DURING ROTATION, BOTH WITH A VISUAL FIELD AND IN ITS ABSENCE. WITH A VISUAL FIELD PRESENT, FOR EXAMPLE, SO THAT A CONFLICT EXISTED BETWEEN THE VISUALLY AND POSTURALLY INDICATED UPRIGHTS, SOME SUBJECTS PERCEIVED THE FIELD AS FULLY ERECT, AND SIMPLY ALIGNED THE ROD WITH ITS MAIN AXES. FOR OTHER SUBJECTS, THE FORCE ACTING ON THE BODY HAD A MUCH STRONGER EFFECT, ACTUALLY CAUSING THE OBJECTIVELY UPRIGHT FIELD ITSELF TO APPEAR TILTED, AND LEADING TO ADJUSTMENTS OF THE ROD WHICH MORE NEARLY CONFORMED WITH THE DIRECTION OF THIS FORCE. THE CONCLUSION PREVIOUSLY REPORTED BY MACH, THAT POSTURAL FACTORS ARE PRIMARY IN PERCEPTION OF THE UPRIGHT, WHICH IS IN CONTRADICTION TO THE FINDINGS OF THE PRESENT STUDY, SEEMS TO BE BASED UPON THE FACT THAT HE GENERALIZED FROM RESULTS OBTAINED WITH THE LATTER TYPE OF SUBJECT ALONE.

WILKIN, H.A. FURTHER STUDIES OF PERCEPTION OF THE UPRIGHT WHEN THE DIRECTION OF THE FORCE ACTING UPON THE BODY IS CHANGED. JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 1952, 43, 9-20.

* ABSTRACT *

SUPPLEMENTING AN EARLIER STUDY OF PERCEPTION OF THE POSITION OF AN ITEM WITHIN A FIELD DURING ROTATION (I.E., DURING DISPLACEMENT OF THE DIRECTION OF THE FORCE ACTING ON THE BODY), THIS STUDY INVESTIGATED THE EFFECT OF ROTATION UPON PERCEPTION OF THE POSITION OF THE BODY ITSELF AND OF THE SURROUNDING FIELD. THE APPARATUS CONSISTED OF A SMALL FULLY-ENCLOSED ROOM WHICH MOVED AROUND A CIRCULAR TRACK. BOTH ROOM AND A CHAIR WITHIN IT

WOULD BE TILTED LEFT AND RIGHT, EITHER TOGETHER OR INDEPENDENTLY. THE S WAS REQUIRED ON SOME TRIALS TO STRAIGHTEN THE ROOM IF IT APPEARED TILTED, AND ON OTHER TRIALS TO STRAIGHTEN HIS BODY IF IT FELT TILTED. ADJUSTMENT OF THE BODY WAS MADE WITH THE ROOM LIGHTED AND DARKENED (I.E. WITH AND WITHOUT A VISUAL FIELD). DATA WERE OBTAINED FOR FOUR RATES OF ROTATION, A DIFFERENT GROUP OF YOUNG ADULT SS BEING USED FOR EACH SPEED.

DURING ROTATION THE ROOM USUALLY HAD TO BE TILTED FROM THE TRUE UPRIGHT TOWARD THE CENTER OF ROTATION TO BE PERCEIVED AS UPRIGHT. THE AVERAGE AMOUNT BY WHICH THE ROOM WAS TILTED, HOWEVER, WAS CONSIDERABLY LESS THAN THE MAGNITUDE OF THE SHIFT OF THE FORCE ON THE BODY. IT WAS FOUND THAT THE BODY ALSO USUALLY HAD TO BE TILTED TOWARD THE CENTER OF ROTATION TO BE PERCEIVED AS UPRIGHT. IT WAS TILTED MUCH LESS, HOWEVER, WHEN AN OBJECTIVELY UPRIGHT FIELD WAS PRESENT THAN WITHOUT A FIELD.

IN GENERAL, THE LOCATION OF THE PERCEIVED UPRIGHT WAS QUITE DIFFERENT WITH A VISUAL FIELD THAN WITHOUT ONE. WHEN AN OBJECTIVELY UPRIGHT FIELD WAS PRESENT, THE PERCEIVED UPRIGHT WAS LOCATED CLOSER TO THE VERTICAL OF THE FIELD, I. E., THE TRUE UPRIGHT, THAN TO THE DIRECTION OF THE DISPLACED FORCE ACTING ON THE BODY, WHEREAS WITHOUT A FIELD IT WAS PLACED CLOSER TO THE FORCE ON THE BODY. WITH INCREASE IN THE RATE OF ROTATION, AN INCREASE IN MAGNITUDE OF SHIFT OF THE PERCEIVED UPRIGHT FROM THE TRUE UPRIGHT OCCURRED UNDER ALL CONDITIONS. THIS RELATIONSHIP DOES NOT SEEM TO BE LINEAR.

MARKED INDIVIDUAL DIFFERENCES WERE OBSERVED AMONG SS IN MANNER OF LOCATING THE UPRIGHT. IN JUDGMENTS OF FIELD POSITION AND BODY POSITION MADE WITH CONFLICTING VISUAL AND POSTURAL STANDARDS, SOME SS RELIED ALMOST EXCLUSIVELY ON ONE OR THE OTHER OF THESE STANDARDS, WHILE OTHER SS COMPROMISED BETWEEN THEM IN VARYING DEGREES. IN JUDGMENTS OF BODY POSITION MADE WITH A POSTURAL STANDARD ALONE, SS DIFFERED IN THE DEGREE TO WHICH THE BODY WAS ALIGNED WITH THE DISPLACED FORCE ACTING UPON IT. DIFFERENCES IN PERCEPTION BETWEEN MEN AND WOMEN WERE ALSO NOTED UNDER CONDITIONS OF CONFLICTING VISUAL AND POSTURAL STANDARDS, WITH WOMEN ADHERING MORE CLOSELY TO THE VISUAL STANDARD.

WOLFE, J.W. AND CRAMER, R.L. ILLUSIONS OF PITCH INDUCED BY CENTRIPETAL ACCELERATION. AEROSPACE MEDICINE, VOLUME 41(10): 1136-1139, OCTOBER 1970.

* ABSTRACT *

EIGHT BASIC AIRMEN AND 17 EXPERIENCED JET PILOTS WERE EXPOSED TO FIVE DIFFERENT LEVELS OF CENTRIPETAL ACCELERATION UNDER TWO SEPARATE CONDITIONS. TRIALS WERE GIVEN WITH AND WITHOUT ILLUMINATION AND WHILE THE SUBJECT WAS FACING TOWARD OR AWAY FROM THE CENTER OF ROTATION. SUBJECTS WERE REQUIRED TO POSITION

THEMSELVES TO THE SUBJECTIVE HORIZONTAL PLANE UNDER EACH OF THESE CONDITIONS. THE ILLUSION OF PITCH DEVELOPED RAPIDLY AND SHOWED LITTLE CHANGE OR ADAPTATION OVER A 4 MINUTE TIME INTERVAL. BOTH THE INEXPERIENCED BASIC AIRMEN AND THE EXPERIENCED JET PILOTS WERE EQUALLY SUSCEPTIBLE TO THE ILLUSION OF PITCH INDUCED BY THE ACCELERATION; THERE WERE NO SIGNIFICANT DIFFERENCES BETWEEN THE TWO GROUPS. PRIMARY SENSORY INPUT APPEARED TO BE FROM THE OTOLITHS AND THE SUBJECTS RESPONSES APPEARED TO BE LINEARLY RELATED TO THE RESULTANT FORCE FOR THE FIVE LEVELS TESTED.

 WARD, C.D. ANTI-MOTION-SICKNESS THERAPY. FIFTH SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE EXPLORATION, HELD AT THE NAVAL AEROSPACE MEDICAL RESEARCH LAB., PENSACOLA, FL., AUG 19-21, 1970. PUBLISHED AS NASA SP-314, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., D.C., 1973.

* ABSTRACT *
 NEITHER ALTERATIONS IN ENVIRONMENTAL TEMPERATURE NOR MODERATE INTAKE OF ALCOHOL WAS FOUND TO ALTER SUSCEPTIBILITY TO MOTION SICKNESS IN SUBJECTS EXPOSED TO ROTATION IN THE PENSACOLA SLOW ROTATION ROOM.

SCOPOLAMINE WITH D-AMPHETAMINE WAS FOUND TO BE THE MOST EFFECTIVE PREPARATION FOR THE PREVENTION OF MOTION SICKNESS UNDER THE EXPERIMENTAL CONDITIONS OF THE STUDIES REPORTED HERE. PROMETHAZINE IN COMBINATION WITH D-AMPHETAMINE WAS IN THE SAME RANGE OF EFFECTIVENESS. DRUG ACTIONS SUGGEST THAT ACETYLCHOLINE AND NOREPINEPHRINE MAY BE INVOLVED IN MOTION SICKNESS.

 WARDRUFF, R.R., SMITH, J.F., FULLER, J.R. AND WEYER, D.C. FULL MISSION SIMULATION IN UNDERGRADUATE PILOT TRAINING; AN EXPLORATORY STUDY FLYING TRAINING DIVISION, AIR FORCE HUMAN RESOURCES LABORATORY, WILLIAMS AIR FORCE BASE, ARIZONA, AFHRL-TR-76-84, DECEMBER 1976.

* ABSTRACT *
 EIGHT UNDERGRADUATE PILOT TRAINING STUDENTS WERE TRAINED TO SPECIFIED LEVELS OF PERFORMANCE IN ALL MAJOR AREAS OF BASIC PILOT TRAINING USING THE ADVANCED SIMULATOR FOR UNDERGRADUATE PILOT TRAINING (ASUPT); HALF WERE TRAINED USING THE PLATFORM MOTION SYSTEM AND HALF WITHOUT. SUBSEQUENTLY, THEY COMPLETED BASIC PILOT TRAINING (TO AIR TRAINING COMMAND (ATC) PHASE STANDARDS) IN T-37 AIRCRAFT. TRAINING HOURS REQUIRED AND CHECK RIDE SCORES WERE COMPILED FOR EACH SUBJECT. SIMILAR DATA WERE COLLECTED FOR A CONTROL GROUP OF EIGHT SUBJECTS TRAINED USING THE CONVENTIONAL ATC SYLLABUS. USING DATA OBTAINED FROM BOTH GROUPS, ESTIMATES OF TRANSFER OF TRAINING PERCENTAGES, AND

TRAINING EFFECTIVENESS RATIOS WERE COMPUTED.

SIMULATOR TRAINED STUDENTS REQUIRED FEWER AIRCRAFT HOURS IN ALL ARTAS OF BASIC LFT AND ACHIEVED CHECK RIDE SCORES EQUAL TO OR BETTER THAN THE CONTROL GROUP. NO SIGNIFICANT OR PRACTICAL DIFFERENCES WERE DOCUMENTED BETWEEN PERFORMANCES OF THE MOTION AND NO-MOTION TRAINED GROUPS FOR ANY CATEGORY OF MANEUVERS.

THIS WAS A FIRST EFFORT TO INCORPORATE A FULL MISSION SIMULATOR INTO AN OPERATIONAL PILOT TRAINING PROGRAM. SEVERAL PROBLEM AREAS WERE IDENTIFIED WHICH MUST BE SOLVED BEFORE FULL SUCCESS CAN BE ACHIEVED. THESE SAME PROBLEMS SHOULD BE RELEVANT TO APPLICATION OF OTHER FULL MISSION SIMULATORS IN OTHER TRAINING PROGRAMS. IN ADDITION, SOME ASPT DEFICIENCIES WERE IDENTIFIED.

WORMER, C. AND R. WILLIAMS ENVIRONMENTAL REQUIREMENTS FOR SIMULATED HELICOPTER/VTOL OPERATIONS FROM SMALL SHIPS AND CARRIERS
REPORT: TM 78-2 RW ROTARY WING AIRCRAFT TEST DIRECTORATE
NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND, 12 APRIL 1978

* ABSTRACT *

THE UNIQUE CHARACTERISTICS OF A HELICOPTER COMBINED WITH THE SHIPBOARD OPERATIONS OF A NAVAL ENVIRONMENT HAVE BEEN SUCCESSFULLY SIMULATED IN DEVICE 2F106, THE SH-2F WEAPONS SYSTEM TRAINER (WST). IT IS EQUIPPED WITH A VITAL III COMPUTER-GENERATED IMAGE (CGI) CALLIGRAPHIC VISUAL SYSTEM. THE DEVELOPMENT AND VALIDATION OF THIS DEVICE HAVE PROVIDED VALUABLE EXPERIENCE ON ENVIRONMENTAL REQUIREMENTS NEEDED TO PERFORM TAKEOFF AND LANDING TASKS FROM SHIPS. TECHNICAL ADVANCES IN THE STATE-OF-THE-ART OF CGI VISUAL SYSTEMS NOW OFFER CAPABILITIES WHICH OVERCOME MANY PREVIOUS LIMITATIONS. THIS PERMITS ADDITIONAL TASKS TO BE SUCCESSFULLY SIMULATED, IMPROVING THE SAFETY AND ECONOMICS OF TRAINING.

THE PAPER DISCUSSES THE SPECIFIC REQUIREMENTS FOR THE SIMULATED ENVIRONMENT TO SATISFACTORILY PROVIDE TRAINING FOR SHIPBOARD TAKEOFF AND LANDING. TEST TECHNIQUES TO VALIDATE TRAINER FIDELITY IN FLYING QUALITIES, PERFORMANCE, AND ENVIRONMENTAL SIMULATION ARE DISCUSSED. THE SPECIFIC SUBJECT OF CALLIGRAPHIC VISUAL SYSTEMS IS EXTENSIVELY COVERED, INCLUDING A REPORT ON THE CURRENT STATE-OF-THE-ART AS RELATED TO THE AT-SEA ENVIRONMENT. FINALLY, THE UTILIZATION OF A HIGH-FIDELITY TRAINER IS EXPLORED FOR RESEARCH AS WELL AS FOR EXPANDED FLEET TRAINING.

HELICOPTER/VTOL OPERATIONS FROM SHIPS CREATE DEMANDING FLYING QUALITIES AND PERFORMANCE REQUIREMENTS. THE ENVIRONMENT IN WHICH TAKEOFF AND LANDING EVOLUTIONS MUST OCCUR HAS A SIGNIFICANT INFLUENCE ON THESE TASKS. AIRCRAFT AND SIMULATOR DESIGNERS, EACH IN THEIR OWN WAY, MUST MAKE APPROPRIATE PROVISION FOR

ENVIRONMENTAL FACTORS, SUCH AS VISUAL LANDING (VLA), SHIP MOTION, TURBULENCE, RELATIVE WIND, AND GROUND EFFECT.

WRENNINGE, B. A SIMULATOR INVESTIGATION TO FIND SUITABLE COMMAND SIGNALS FOR A THREE-DEGREES OF FREEDOM SIMULATOR MOTION SYSTEM, ASSOCIATION FRANCAISE DES INGENIEURS ET TECHNICIENS DE L'AERONAUTIQUE ET DE L'ESPACE, CONGRES INTERNATIONAL AERONAUTIQUE, 8TH, PARIS, FRANCE, MAY 29-31, 1967, PAPER 50 P.

* ABSTRACT *

AN EXPERIMENTAL STUDY HAS BEEN PERFORMED AT THE FOSIM SIMULATOR PLANT OF THE DEPARTMENT OF AERONAUTICS AT THE ROYAL INSTITUTE OF TECHNOLOGY IN STOCKHOLM IN ORDER TO DETERMINE HOW THE AVAILABLE MOTION SYSTEM SHOULD BE COMMANDED WHEN PERFORMING LANDING SIMULATION OF A MODERN FIGHTER TYPE AIRCRAFT.

THE AIRCRAFT SIMULATED WAS THE J-35 (DRAGON) AND THE WORK WAS CARRIED OUT IN SEVERAL STEPS LEADING TO A FINAL TEST, WHERE SIX TEST PILOTS, WELL ACQUAINTED WITH THE J-35, PARTICIPATED. THE PILOTS EVALUATED THE DIFFERENT SUGGESTED COMMAND SIGNALS AND SIMPLY CHOSE THOSE WHO GAVE THE MOST J-35 SIMILAR 'FEEL' OF FLYING.

THE WORK PROVED WELL WORTH IT BECAUSE ALL THE EARLIER USED COMMAND SIGNALS WERE CHANGED ONE WAY OR ANOTHER.

IT WAS FOUND THAT THE PILOTS COULD EASILY BE FOOLED WHEN EVALUATING THE FLYING QUALITIES OF THE SIMULATED AIRCRAFT IF THE MOTION SYSTEM COMMAND SIGNALS WERE UNSUITABLE.

XHIGNESSE, SELECTIVE SURVEY OF FRENCH DEVELOPMENTS IN FLIGHT SIMULATORS AND FLIGHT INSTRUMENTS, 1. FLIGHT SIMULATORS, WADC TR 57-378, JUNE 1958.

ABSTRACT NOT AVAILABLE AT TIME OF PUBLICATION

YALOG, F. A CATALOG OF SIMULATORS FOR TRAINING SPACE FLIGHT PERSONNEL. PROJECT SETE, 'NEW YORK UNIVERSITY', SCHOOL OF ENGINEERING AND SCIENCE, RESEARCH DIVISION, MAY 1965

* ABSTRACT *

THIS REPORT IS A COMPILATION OF SHORT DESCRIPTIONS OF GROUND-BASED SIMULATORS FOR THE TRAINING OF CREW MEMBERS OR FOR RESEARCH INTO THE PROBLEMS OF CREW OPERATIONS AND CONTROL OF MANNED SPACECRAFT.

THE SIMULATORS DESCRIBED HEREIN BELONG TO TWO GENERAL CLASSES: (1) FIXED OR MOVING BASE REPRESENTATIONS OF SPACECRAFT CREW COMPARTMENTS, AND (2) DEVICES USED TO EXPOSE A HUMAN SUBJECT TO SPACE FLIGHT RELATED ENVIRONMENTS SUCH AS ACCELERATION AND PRESSURE PROFILES, MULTI-AXIS ROTATIONS, AND REDUCED GRAVITY STATES.

THIS REPORT DOES NOT COVER UNMANNED SIMULATORS, DEVICES USED PRIMARILY FOR ENVIRONMENTAL TESTING OF EQUIPMENT, GROUND-BASED AIRCRAFT RATHER THAN SPACECRAFT SIMULATORS, VARIABLE STABILITY AIRCRAFT, OR OTHER AIRBORNE SIMULATION FACILITIES. IN ORDER TO PROVIDE THE USER WITH READY ACCESS TO SURVEY-TYPE DOCUMENTS WHICH DO DESCRIBE SUCH EQUIPMENTS, AN APPENDIX WHICH PROVIDES BRIEF DESCRIPTIONS OF SOME SIGNIFICANT CATALOGUES IS INCLUDED. (AUTHOR)

YOUNG, L.R. SOME EFFECTS OF MOTION CUES ON MANUAL TRACKING; JOURNAL OF SPACECRAFT AND ROCKETS, OCTOBER 1967, PAGES 1300-1303 VOL. 4, NO. 10.

* ABSTRACT *

ALTHOUGH SUSTAINED HIGH ACCELERATION OR VIBRATION CAN HAVE A DELETERIOUS EFFECT ON A PILOT'S TRACKING ABILITY, THERE ARE SOME SITUATIONS IN WHICH MOTION CUES, AS FELT IN FLIGHT OR MOVING-BASE SIMULATION, YIELD A SIGNIFICANT IMPROVEMENT IN PILOT PERFORMANCE. THE FIRST OF THESE SITUATIONS IS IN A CONTROL TASK REQUIRING MORE LEAD COMPENSATION THAN IS EASILY DEVELOPED FROM VISUAL DISPLAYS. THE VESTIBULAR AND TACTILE SENSATIONS CONTRIBUTE VELOCITY AND ACCELERATION INFORMATION WHICH IS USED IN STABILIZATION. EXPERIMENTS ON CONTROL OF INVERTED PENDULUMS AND VTOLIS WITH AND WITHOUT MOTION CUES ARE DISCUSSED. TESTS OF LABYRINTHINE DEFECTIVE PATIENTS ON SIMILAR TASKS DEMONSTRATED THE CRITICAL IMPORTANCE OF VESTIBULAR INPUTS. THE SECOND SITUATION REQUIRED RAPID ADAPTATION TO CONTROLLED ELEMENT FAILURES IN A SIMULATED BLIND LANDING EXPERIMENT. OTHER TESTS SHOWED MOTION EFFECTS TO BE IMPORTANT IN A CLASS OF FLEXIBLE BOOSTER CONTROL PROBLEMS. THESE RESULTS WERE COMBINED WITH MANY COMPARISONS OF FIXED BASE-MOVING BASE FLIGHT EXPERIMENTS IN THE LITERATURE TO ARRIVE AT SOME GENERAL CONCLUSIONS REGARDING THE EFFECTS OF MOTION CUES ON TRACKING.

YOUNG, L.R. ON BIOCYBERNETICS OF THE VESTIBULAR SYSTEM. REPORT NASA SP-192, FOURTH ANNUAL NASA-UNIVERSITY CONFERENCE ON MANUAL CONTROL, HELD AT U. OF MICHIGAN, MAR. 21-23, 1968.

* ABSTRACT *

THIS PAPER DESCRIBES THE CHARACTERISTICS OF THE HUMAN VESTIBULAR

SYSTEM MODELLED FROM THE POINT OF VIEW OF CONTROL THEORY. CONTROL SYSTEM DESCRIPTIONS OF THE GRAVIRECEPTORS HAD BEEN ALMOST NONEXISTENT PRIOR TO THESE STUDIES. THE COMPLETE VESTIBULAR MODEL PRESENTED IN THIS PAPER DESCRIBES MOST NONVISUAL DYNAMIC ORIENTATION PHENOMENA IN A MANNER FAMILIAR TO CONTROL ENGINEERS. PRACTICAL SAMPLES ARE INCLUDED TO SHOW THE WAY VESTIBULAR STIMULATION CONTRIBUTES TO THE PILOT'S CONTROL COMPENSATION IN A CLOSED-LOOP VEHICLE CONTROL TASK. (AUTHOR).

YOUNG, L.R., 'ON VISUAL VESTIBULAR INTERACTIONS', FIFTH NASA SYMPOSIUM ON THE ROLE OF THE VESTIBULAR ORGANS IN SPACE EXPLORATION, HELD AT THE NAVAL AEROSPACE MEDICAL RESEARCH LAB., PENSACOLA, FL., AUG 19-21, 1970. PUBLISHED AS NASA SP-314, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASH., D.C., 1973.

* ABSTRACT *

EXPERIMENTAL EVIDENCE IS PRESENTED REGARDING VISUAL-VESTIBULAR INTERACTION, AND THE RESULTS OF THREE STUDIES ON THE SUBJECT ARE BRIEFLY NOTED. AN ATTEMPT TO PUT TOGETHER SOME OF THESE OBSERVATIONS WITH ELEMENTARY NOTIONS OF A VISUAL-VESTIBULAR INTERACTION PROGRAM IS SHOWN IN THE FORM OF A FLOW-CHART REPRESENTATION OF A POSSIBLE MODEL. THIS IS A NONLINEAR MODEL IN WHICH VISUAL AND VESTIBULAR INFLUENCES ARE LINEARLY WEIGHTED WHEN THEY ARE IN RELATIVE AGREEMENT BUT SWITCH TO THE MORE 'BELIEVABLE' ONE WHEN THEY ARE IN DISAGREEMENT. A SOLUTION TO THE HUMAN SPACE-ORIENTATION PROBLEM IS DEPICTED BY A SCHEMA FOR OPTIMAL SUBJECTIVE ORIENTATION BASED ON SEVERAL SENSORY MODALITIES.

YOUNG, L.R. DEVELOPMENTS IN MODELLING VISUAL-VESTIBULAR INTERACTIONS, AMRL-TR-71-14, AEROSPACE MEDICAL RESEARCH LABORATORY, AEROSPACE MEDICAL DIV, AIR FORCE SYSTEMS COMMAND, WRIGHT-PATTERSON AFB, OH 45433 JANUARY 1971

* ABSTRACT *

AN EARLIER REPORT DESCRIBED A PHYSICAL ANALOG OF THE HUMAN VESTIBULAR SYSTEM, WHICH SIMULATED NYSTAGMIC EYE MOVEMENTS AND SUBJECTIVE SENSATION OF MOTION BASED ON SENSED MOTION OF THE HEAD. THIS REPORT REVIEWS A NUMBER OF POSSIBLE EXTENSIONS TO THIS MODEL--EMPHASIZING THE COMPLEX INTERACTIONS AMONG VISUAL, OTOLITH, AND CANAL STIMULI. MODELS ARE DISCUSSED FOR SEMICIRCULAR CANALS AND OTOLITHS, THE VESTIBULO-OCULAR REFLEX, OPTOKINETIC AND GALVANIC STIMULATION OF EYE MOVEMENTS, COUNTERROLLING, VISUAL-VESTIBULAR INTERACTION AND PURSUIT EYE MOVEMENTS.

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YOUNG, L.R. VISUAL AND MOTION REQUIREMENTS FOR FLIGHT SIMULATION AND RIDE QUALITY INVESTIGATION. SEMIANNUAL PROGRESS REPORT, 1 JAN - 30 NOV. 1972 NASA-CR-133193

ABSTRACT NOT AVAILABLE AT TIME OF PUBLICATION

YOUNG, L.R. SEMI ANNUAL STATUS REPORT: INTEGRATION OF VISUAL AND MOTION CUES FOR SIMULATOR REQUIREMENTS AND RIDE QUALITY INVESTIGATION. MIT, NASA GRANT NGR 22-009-701, MAY 1975-NOVEMBER 1975.

* ABSTRACT *

DURING THIS REPORTING PERIOD, WORK HAS CONTINUED ON THE USE OF THE BRMSBY MODEL FOR PREDICTING VESTIBULAR RESPONSE, SPECIFICALLY IN A COORDINATED TURN; ON THE USE OF VISUAL CUES IN LANDING, INCLUDING A PILOT EXPERIMENT USING THE VIDEO TAPES MADE AT LANGLEY; A COMPREHENSIVE REVIEW OF PRESENT DAY COMPUTER STATE-OF-THE-ART WAS MADE AND A DECISION CONCERNING THE BEST SYSTEM FOR THE MAN VEHICLE LABORATORY; AND FINALLY, SEVERAL PAPERS HAVE BEEN PUBLISHED CONCERNING THE WORK PERFORMED UNDER THIS GRANT.

YOUNG, L.R. INTEGRATION OF VISUAL AND MOTION CUES FOR SIMULATOR REQUIREMENTS AND RIDE QUALITY INVESTIGATION. MAN-VEHICLE LABORATORY, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, NGR 22-009-701, (NASA-CR-148479), SEMIANNUAL STATUS REPORT, DEC. 1975-JUN 1976.

* ABSTRACT *

THE RESEARCH COVERED BY THIS GRANT IS AIMED AT THE DEVELOPMENT OF PRACTICAL TOOLS WHICH CAN EXTEND THE STATE-OF-THE ART OF MOVING BASE FLIGHT SIMULATION FOR RESEARCH AND TRAINING. THERE ARE TWO MAIN APPROACHES TO THIS RESEARCH EFFORT REPORTED ON IN THIS PROGRESS SUMMARY:

(1) APPLICATION OF THE VESTIBULAR MODEL FOR PERCEPTION OF ORIENTATION BASED ON MOTION CUES: OPTIMUM SIMULATOR MOTION CONTROLS.

(2) VISUAL CUES IN LANDING.

VERY SIGNIFICANT PROGRESS HAS BEEN MADE WITH RESPECT TO THE FIRST GOAL, INCLUDING THE COMPLETION OF A MASTER'S THESIS ON THIS SUBJECT BY MR. JOSHUA BORAH. EXPERIMENTS ARE UNDERWAY ON THE SECOND PORTION AFTER INITIAL PILOT EXPERIMENTS WHICH WERE PERFORMED DURING THIS REPORTING PERIOD.

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IN ADDITION TO THE M.S. THESIS, THERE IS A PAPER IN PRESS AND ANOTHER WHICH HAS BEEN SUBMITTED FOR PUBLICATION. THESE PAPERS ARE APPENDED TO THIS PROGRESS REPORT.

YFANG, L.R. VISUALLY INDUCED MOTION IN FLIGHT SIMULATION. PAPER PRESENTED AT AGARD MEETING ON FLIGHT SIMULATION, BRUSSELS, APRIL 1978.

* ABSTRACT *

MUCH OF THE ATTENTION TO VISUAL DISPLAYS FOR FLIGHT SIMULATION IN RECENT YEARS HAS BEEN DEVOTED TOWARD PRECISION WIDE FIELD PRESENTATIONS. THE SIGNIFICANT ADVANCES IN MULTISCREEN COMPUTER IMAGE GENERATION AND POINT LIGHT SOURCE DISPLAYS HAS QUITE LITERALLY WIDENED OUR HORIZONS FOR PRESENTATION OF OUT-THE-WINDOW INFORMATION. MOST ATTENTION HAS BEEN DEVOTED TO THE PRECISE STATIC DISPLAY CONSIDERATIONS INCLUDING PERSPECTIVE, GRAIN AND CONTRAST. RELATIVELY LESS ATTENTION HAS BEEN DEVOTED TO THE DYNAMIC PROPERTIES OF THE VISUAL SCENE AND IN PARTICULAR THE ROLE OF THE MOVING WIDE FIELD PRESENTATION IN SUSTAINING A PILOT'S MOTION SENSE. THIS PAPER ADDRESSES THE EXPERIMENTAL DATA ACCUMULATING ON THE SUBJECT OF VISUALLY INDUCED MOTION FOR ALL LINEAR AND ANGULAR DEGREES OF FREEDOM. IN PARTICULAR, WE DISCUSS VISUALLY INDUCED YAW (CIRCULARVECTION) RESULTING FROM A MOVING WIDE FIELD PRESENTATION, AND ITS INTERACTION WITH VESTIBULAR YAW CUES GENERATED BY BASE MOTION. A MODEL IS PRESENTED FOR THE INTERACTION BETWEEN VISUAL AND MOTION CUES IN YAW WHICH RATIONALIZES THE HIGH FREQUENCY UTILIZATION OF VESTIBULAR CUES TO SUPPORT SUSTAINED ANGULAR VELOCITY. THE CONSIDERATIONS APPLY TO VISUALLY INDUCED LINEAR VELOCITY (LINEARVECTION) AND INTERESTING ASYMMETRIES IN THE FORE-AFT DIRECTION ARE NOTED. FINALLY, VISUALLY INDUCED PITCH AND ROLL ARE DISCUSSED AND MODELLED IN TERMS OF CONFLICT BETWEEN THE VISUALLY INDUCED MOTION AND THE INFORMATION REGARDING ATTITUDE BASED UPON GRAVICEPTOR SIGNALS.

YFANG, L.R., CURRY, E.E. AND OMAN, CM
RESEARCH ON INTERPRETATION OF VISUAL AND MOTION CUES FOR FLIGHT SIMULATION AND RIDE QUALITY INVESTIGATION. MIT MAN-VEHICLE LAB. PROGRESS REPORT APRIL-OCTOBER 1974, NASA-CR-140981

* ABSTRACT *

THE PRIMARY GOAL OF THIS RESEARCH PROGRAM IS THE DEVELOPMENT OF MULTI-INPUT MODELS FOR THE OPTIMUM USE OF VISUAL AND MOTION CUES IN FLIGHT SIMULATION. PAST REPORTS HAVE EMPHASIZED DEVELOPMENT OF MODELS FOR THE PROCESSING OF VISUAL CUES ASSOCIATED WITH STRUCTURED AND NON-STRUCTURED VISUAL SCENES, REFINEMENT OF MODELS FOR SPATIAL ORIENTATION BASED UPON SEMI-CIRCULAR CANAL AND OTOLITH FUNCTION, THE COMBINATION OF LINEAR

AND ANGULAR ACCELERATION CUES IN NON-VISUAL SENSING AND THE INTEGRATION OF VISUAL AND VESTIBULAR CUES ASSOCIATED WITH MOVING VISUAL FIELDS. THE WORK WHICH HAS TAKEN PLACE DURING THE LAST SIX MONTHS HAS BEEN CONCENTRATED ON

- (1) THE TESTING OF THE APPLICABILITY OF OUR MODELS BY APPLYING THE BRMSBY MODEL FOR VISUAL-VESTIBULAR INTERACTIONS TO A REALISTIC SIMULATION.
- (2) DESIGN AND DEVELOPMENT OF A FIVE DEGREE OF FREEDOM ORIENTATION INDICATOR
- (3) REFINEMENT OF THE LINK GAT-1 DISPLAY SYSTEM
- (4) EXTENDING THE STUDY OF LINEARVECTION IN THE VERTICAL DIRECTION.
- (5) CONTINUED INVESTIGATION OF THE RELATIONSHIP BETWEEN VESTIBULAR STIMULATION AND VISUALLY INDUCED ROLL, USING THE INDICATOR OF COUNTER-ROLLING EYE MOVEMENTS.
- (6) EXPERIMENTS ON SIMULATOR VISUAL THRESHOLDS.

YOUNG, L.R., DICIGANS, J., MURPHY, R. AND BRANDT, T.
INTERACTION OF OPTOKINETIC AND VESTIBULAR STIMULI IN MOTION PER-
CEPTION, (REVISED JULY 28, 1972) ACTA OTOLARYNG, 1973, 76,
24-31.

* ABSTRACT *

THE SENSATION OF SELF-ROTATION (CIRCULAR-VECTION) WAS PRODUCED BY ROTATION OF A STRIPE PATTERN TO THE LEFT OR TO THE RIGHT AT CONSTANT ANGULAR VELOCITY. DURING CIRCULARVECTION, SUBJECTS WERE RANDOMLY ACCELERATED IN CONSTANT ACCELERATION STEPS. THE MAJOR EXPERIMENTAL FINDINGS ARE:

1. THRESHOLDS FOR DETECTION OF ANGULAR ACCELERATION ARE RAISED WHEN THIS ACCELERATION IS OPPOSITE TO THE DIRECTION OF CIRCULAR-VECTION. TIMES TO DETECT THESE ACCELERATIONS ARE SIMILARLY INCREASED.
2. MAGNITUDE ESTIMATES OF ANGULAR VELOCITY SHOW THE EFFECT OF A VISUALLY INDUCED VELOCITY OFFSET WHICH IS INCREASED SLIGHTLY BY VESTIBULAR RESPONSES IN THE SAME DIRECTION AND DECREASED MARKEDLY WHEN THE VESTIBULAR RESPONSES ARE IN THE DIRECTION OPPOSITE TO SELF-ROTATION.
3. MANY OF THE EFFECTS OF ANGULAR ACCELERATION ON PERCEIVED VELOCITY ARE ACCURATELY PREDICTED BY THE ADAPTATION MODEL OF THE VESTIBULAR SYSTEM. HOWEVER, AN IMPORTANT NONLINEAR INTERACTION EXISTS WHEREBY RAPIDLY OCCURRING CONFLICTS BETWEEN VISUAL AND VESTIBULAR SENSATION, ESPECIALLY THOSE

INVOLVING DIRECTION DISPARITIES, RESULT IN A PRECIPITOUS DECLINE IN CIRCULAR-VECTION AND TEMPORARY DOMINATION BY THE VESTIBULAR RESPONSE.

 YOUNG, L.R. AND MEIRY, J.L. 'MANUAL CONTROL OF AN UNSTABLE SYSTEM WITH VISUAL AND MOTION CUES'. IEEE INTERNATIONAL CONVENTION RECORD, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, NEW YORK, 1965, VOL. 13, PART 6 PP. 123-137.

* ABSTRACT *
 2 SUBJECTS CONTROLLED CABIN DRIVEN TO BE AN UNSTABLE ROLL PENDULUM, BY USING VISUAL CUES ONLY, VESTIBULAR AND TACTILE CUES ONLY, AND VISUAL PLUS VESTIBULAR AND TACTILE CUES. WHEN MOTION CUES ADDED, OPERATOR CAN CONTROL HIGHER DIVERGENT FREQUENCIES AND DEVELOP GREATER PHASE LEAD.

 YOUNG, L.R., BMAN, C.M., CURRY, R.E. AND DICHGANS, J.M. A DESCRIPTIVE MODEL OF MULTISENSOR HUMAN SPATIAL ORIENTATION WITH APPLICATIONS TO VISUALLY INDUCED SENSATIONS OF MOTION. AIAA PAPER NO. 73-915, PRESENTED AT THE AIAA VISUAL AND MOTION SIMULATION CONFERENCE, PALO ALTO, CA SEP 10-12, 1973

* ABSTRACT *
 THE PHYSIOLOGICAL SYSTEMS UNDERLYING HUMAN SENSATION OF SPATIAL ORIENTATION AND POSTURAL CONTROL ARE OF PARTICULAR INTEREST FROM A CONTROL POINT OF VIEW AND ARE REVIEWED IN THE FIRST PART OF THE PAPER. THE SECOND PART OF THE PAPER SUMMARIZES RECENT EXPERIMENTS INVESTIGATING VISUALLY INDUCED MOTION SENSATIONS.

 YOUNG, L.R., BMAN, C.M. AND DICHGANS, J.D. INFLUENCE OF HEAD ORIENTATION ON VISUALLY INDUCED PITCH AND ROLL SENSATIONS. 'AVIATION SPACE AND ENVIRONMENTAL MEDICINE' 46(3): 264-268, 1975.

* ABSTRACT *
 OBSERVERS VIEWING ROTATING SCENES IN THEIR PERIPHERY FREQUENTLY EXPERIENCE SELF-MOTION IN THE OPPOSITE DIRECTION. A FULL FIELD (360 DEGREES) FLIGHT SIMULATOR PROJECTION SYSTEM WAS USED TO INVESTIGATE THE SENSATIONS RESULTING FROM PITCH, ROLL, AND YAW STIMULI AT VARIOUS HEAD ORIENTATIONS. STEADY YAW RATE (CIRCULARVECTION) AND DEVELOPMENT OF A CONSTANT ROLL TILT ANGLE, FOR THE HEAD ERECT AND CONSTANT VELOCITY YAW AND ROLL STIMULI, CONFORMED PREVIOUS REPORTS. PITCH STIMULI ALSO WERE FOUND TO PRODUCE A SENSATION OF TILTING TO A STEADY PITCH ANGLE, WHICH WAS MUCH STRONGER FOR PITCH FORWARD THAN BACKWARD.

PITCH AND ROLL EFFECTS WERE STRONGLY DEPENDENT ON HEAD POSITION, INCREASING FOR THE HEAD ROLLED 90 DEGREES TO THE SIDE OR INVERTED AND DECREASING FOR THE HEAD PITCHED 25 DEGREES FORWARD. THESE RESULTS SUPPORT A HYPOTHESIS THAT VISUALLY INDUCED TILT IS LIMITED BY CONFLICT WITH OTOLITH INFORMATION.

ZACHARIAS, G.L., 'MOTION SENSATION DEPENDENCE ON VISUAL AND VESTIBULAR CUES', PH.D. THESIS, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, MIT, SEPTEMBER 1977.

NO ABSTRACT YET

ZACHARIAS, G.L. AND YOUNG, L.R., 'MANUAL CONTROL OF YAW MOTION WITH COMBINED VISUAL AND VESTIBULAR CUES', PRESENTED AT THE 13TH ANNUAL CONFERENCE OF MANUAL CONTROL, MIT, JUNE 1977.

* ABSTRACT *

MEASUREMENTS ARE MADE OF MANUAL CONTROL PERFORMANCE IN THE CLOSED-LOOP TASK OF NULLING PERCEIVED SELF-ROTATION VELOCITY ABOUT AN EARTH-VERTICAL AXIS. SELF-VELOCITY ESTIMATION WAS MODELLED AS A FUNCTION OF THE SIMULTANEOUS PRESENTATION OF VESTIBULAR AND PERIPHERAL VISUAL FIELD MOTION CUES. BASED ON MEASURED LOW-FREQUENCY OPERATOR BEHAVIOR IN THREE VISUAL FIELD ENVIRONMENTS, A PARALLEL CHANNEL LINEAR MODEL IS PROPOSED WHICH HAS SEPARATE VISUAL AND VESTIBULAR PATHWAYS SUMMING IN A COMPLEMENTARY MANNER. A CORRECTION TO THE FREQUENCY RESPONSES IS PROVIDED BY A SEPARATE MEASUREMENT OF MANUAL CONTROL PERFORMANCE IN AN ANALOGOUS VISUAL PURSUIT NULLING TASK. THE RESULTING DUAL-INPUT DESCRIBING FUNCTION FOR MOTION PERCEPTION DEPENDENCE ON COMBINED CUE PRESENTATION SUPPORTS THE COMPLEMENTARY MODEL, IN WHICH VESTIBULAR CUES DOMINATE SENSATION AT FREQUENCIES ABOVE 0.05 HZ. THE DESCRIBING FUNCTION MODEL IS EXTENDED BY THE PROPOSAL OF A NON-LINEAR CUE CONFLICT MODEL, IN WHICH CUE WEIGHTING DEPENDS ON THE LEVEL OF AGREEMENT BETWEEN VISUAL AND VESTIBULAR CUES.

ZUCCARO, C.J.
THE FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT - A NEW AERONAUTICAL RESEARCH TOOL. AIAA PAPER NO. 70359, 'AIAA VISUAL AND MOTION SIMULATION TECHNOLOGY CONFERENCE', CAPE CANAVERAL, FLORIDA, MARCH 16-18, 1970.

* ABSTRACT *

THIS PAPER DISCUSSES THE FLIGHT SIMULATOR FOR ADVANCED AIRCRAFT (FSA4), THE NEWEST AND MOST SOPHISTICATED PILOTED MOTION

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SIMULATOR AT NASA AMES RESEARCH CENTER. THE SIMULATOR'S MOTION SYSTEM PROVIDES SIX DEGREES OF FREEDOM TO A THREE-MAN TRANSPORT TYPE CAB. THE FSAA'S MOST DRAMATIC FEATURE IS ITS UNIQUE 100 FT LATERAL TRAVEL. RESEARCH OPERATIONS ON THE FSAA HAVE INCLUDED INVESTIGATIONS RELATING TO THE DEVELOPMENT OF IMPROVED HANDLING QUALITIES AND AIRWORTHINESS CRITERIA FOR LARGE JET TRANSPORTS. EVIDENCE OBTAINED OF TOTAL SIMULATOR PERFORMANCE INDICATED THAT THE FSAA WILL PROVIDE SIMULATION CAPABILITIES NOT BEFORE AVAILABLE FOR AERONAUTICAL RESEARCH. HOW THIS SIMULATOR IS CONTROLLED AND UTILIZED IN COMBINATION WITH OTHER CUE PRODUCING DEVICES WILL BE SHOWN. THE PROBLEM AREAS ENCOUNTERED IN MAKING FSAA OPERATIONAL WILL ALSO BE DISCUSSED. (AUTHOR)

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